Control ENGINEERING

INSTRUMENTATION AND CONTROL SYSTEMS

A McGraw-Hill Publication

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MAY 1961

Autocompensating Gyro Errors

RAPID Controls Rocket Reliability

Hot Gas Servoactuators

Measuring Turbojet Duct Pressures

Economic Optimum Valve Sizing

Minimizing Nuclear Gaging Errors

Computing-Logging Scoreboard

Control Computer Priority Interrupt

Robot Learns New Job With Ease

Machinist Dial-Programs Control Tapes

Hydraulic Logic: What's Its Potential?

Computing Lumber Yard Throughput

High-Speed Photo Data Processing

Medical Monitoring for Safe Surgery

Incremental-Servo Synchronization

European Report: Mesucora Preview

Television Switching Control

Industrial Electronic-Control Markets

Simplified Design of Moving Coils

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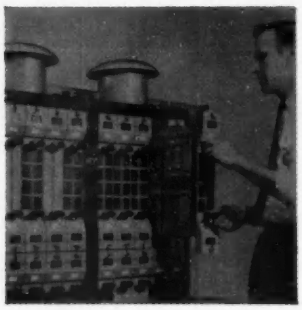

computers that pace man's expanding mind

CIRCLE 223 ON READER SERVICE CARD

BRIEF SPECIFICATIONS

OUTPUT VOLTAGE	1.000 to 502.110 volts, variable in 100-, 10-, 1-, 0.1-, 0.01-, and 0.001-volt steps
OUTPUT CURRENT	Up to 20 ma
STABILITY	±0.0025%
OUTPUT VOLTAGE CALIBRATION	0.01% of setting ±0.0002V
LOAD REGULATION	0.002% or ±100 μV, no load to full load
LINE REGULATION	0.002%, 10% change in line voltage
METER ACCURACY	4% of full scale
OUTPUT Z	<0.01 ohm, DC
FLOATING OUTPUT	>1000 megohms resistance between chassis and either output terminal; current between either output terminal and chassis <0.5 μampere DC, <4 μampere at 60 cps
RESPONSE TIME	0.2 millisecond
PRICE	$1280.00

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The EW Model 6190 is one of a complete line of solid state, modular time code equipment which includes time code generators, time code translators, timing terminals, and universal tape search equipment.

Complete technical information on the Model 6190 Time Code Generator is ready now. Call your nearby knowledgeable Epsco-West engineering representative or address Dept. 21.

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In the Model 6190, all pulse widths and timing are directly derived from the digital dividers and time accumulator by diode matrices. No one-shot circuits are used. Information is not transferred from one register to another. No "stub" counter chains are used. These design features provide absolute synchronism and minimum distortion. Modulation occurs precisely at the true positive going zero-axis point on the carrier.

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KEY SPECIFICATIONS

Input Signal

100 kc, 1-volt RMS, to impedance of 10,000 ohms. An internal frequency standard may be supplied as optional equipment.

Outputs

1. Logic Output, 36-bit parallel BCD (—12v for binary "zero", 0-volts for binary "one").
2. 20-bit, 1 ppm on 100 cps carrier, 1 hour time frame.
3. 28-bit, 2 pps on 100 cps carrier, 1 minute time frame.
4. 36-bit, 100 pps on 1000 cps carrier, 1 second time frame.
5. Three outputs of the 100 pps, 2 pps and 1 ppm modulation pulses at 2 milliampere max. for driving galvanometers.
6. Relay closure at 1 ppm, 28-bit, 2 pps code, closure for pulse durations.
7. 1 pps at 1-volt, synch pulse, accessible front and rear.
8. 1 pps relay closure of 200 ms.
9. Mixed tones output; 100kc, 50kc, 25kc, 12.5kc, 6.25kc, 3.125kc sine waves.

Elapsed-Time Range
399 days 23 hr. 59 min. 59 sec.

Accuracy
Dependent only on reference oscillator.

Size
19" wide by 10½" high x 18" deep.

Control ENGINEERING

MAY 1961

VOL. 8 NO. 5

Published for engineers and technical management men who are responsible for the design, application, and test of instrumentation and automatic control systems

83 **Hydraulic Logic: What's Its Potential?**
H. H. GLAETTLI of IBM, Zurich, divulges that signal-level hydraulic switching units, which can be plastic molded, show good promise as low-cost, fast-operating logic networks.

87 **Minimizing Measurement Errors in Nuclear Gages**
N. Z. ALCOCK and *S. K. GHOSH* of Canada describe error sources in nuclear level, density, and thickness gages, derive equations for reducing errors, and give five examples.

93 **Television Switching Control**
E. J. SCHUBERT of Pasadena, Calif., devises a special digital computer that stores switching sequences for a TV day and carries them out in synchronization with real time.

99 **Hot Gas Control Systems—II: Designing a Hot Gas Servoactuator**
H. A. POOLE, JR. and *E. A. DEMERS* of Walter Kidde apply hot gas servoactuators to the real problem of positioning an aerospace vehicle's aerodynamic control surfaces.

109 **Control Valves—First Cost vs Operating Cost**
W. J. SCHMIDT of Stone & Webster Engineering Corp. considers economics; argues that control valve sizing should be based on smallest annual operating cost, not first cost.

113 **Data File 48—Loaded Parallel-T RC Filters**
C. T. STELZRIED of Jet Propulsion Lab presents complete graphical solutions for finding attenuation and phase of parallel-T networks with a finite source and load.

116 **Incremental Servos—Part V: Interlocking Steppers**
S. M. BAILEY of Vitro Corp. of America completes series on stepper motors by discussing absolute interlocking incremental controls and synthesis of interlocking systems.

121 **Autocompensation of Errors in Gyros and Accelerometers**
J. M. SLATER of Autonetics demonstrates that a sensor's fixed but unknown errors can be eliminated by reversing the measuring device for several cycles to cancel its error.

123 **Simplified Equations Speed Moving Coil Design**
W. G. HOLZBOCK of Birmingham, Mich. designs moving coils for positioning a control system regulating element by adopting simplifying assumptions about materials.

INFORMATION SYSTEMS

127 **Priority Interrupt in Control Computers**
S. B. DINMAN and *R. W. SONNENFELDT* of Radio Corp. of America explain two priority interrupt methods for injecting urgent problems into a computer for fast solution.

134 **RAPID Controls Rocket Engine Reliability**
G. E. OLSON of Rocketdyne engineers an information system that issues complete reliability data on rocket engine components by fast processing of recorded test failure data.

137 **Auxiliary Processors Speed Large Computing System**
H. I. COHEN of Sylvania Electric Products Co. unveils the main features of the big 9400 data system that communicates with input and output via small auxiliary processors.

Continued on next page

IDEAS AT WORK

141 **Industrial Robot Learns New Job With Ease**
M. J. DUNNE of Consolidated Controls builds a robot for repetitive, temporary jobs.

143 **Finding Thermistor Coefficients at Nonstandard Temperatures**
L. A. AXLEROD of Powers Regulator graphs thermistor relationship to speed design.

145 **Electromechanical Transducer Measures Pressure Ratio Directly**
R. H. MYERS of Chance Vought monitors static to total pressure ratio for turbojets.

147 **Relays and Counters Compute Timber Yard Throughput**
J. MISRAHI of New Electronic Products groups prosaic control units to gage lumber.

149 **Machinist Dial-Programs Own Control Tapes**
F. L. GOSNELL of Wang Laboratories simplifies preparation of numerical control tape.

WHAT'S NEW IN THE CONTROL FIELD

25 **Newsbreaks in Control**
Warehousing machine tries again; how radiation affects controls; Little Gypsy starts up.

27 **Control News Potpourri**
Missile test raster display; bilingual converter; delays plague computer-control start up.

29 **Military Rapid Data Processing to Make Industrial Debut**
Technique devised for aerial cameras is to be applied soon to industrial data processing.

32 **New Gear Needed to Move the Literature Mountain**
Abstracting sciences group hears that computers barely keep pace with technical writing.

32 **VA Steps Up Medical Electronics Study**
Five approaches are being studied to use monitoring gear to make tricky operations safer.

39 **French Spectacular**
French control makers stage Mesucora to win a bigger share of Europe's growing market.

42 **Around the Business Loop**
Electronics sets hopes on industrial markets; streamlined recruiting at the trade shows.

21 **Control Personality—J. A. ASELTINE**
A systems manager puts sophisticated controls to work in missiles and space vehicles.

77 **Industry's Pulse—Status of Computer-Logging**
Census of process control computers for data logging, monitoring, and operating guides.

81 **Editorial—"Automation"—The Whipping Boy**
A stumbling block to blame for the world's troubles impedes true technological progress.

151 **New Product Developments**
Production data system accepts clock, card, and keyboard inputs; prints out two-use form.

200 **Abstracts of Technical Papers**
Aircraft landing problem demonstrates predictive control, sets logic and model criteria.

10 Shoptalk
14 Feedback
192 Bulletins & Catalogs
202 New Books
204 Meetings Ahead
208 Reprints

CONTROL ENGINEERING, May, 1961, Vol. 8, No. 5. Published monthly by McGraw-Hill Publishing Company, Inc. Executive, editorial, circulation, and advertising offices: 330 West 42nd Street, New York 36, N. Y. Printed in Albany, N. Y.: second class postage paid at Albany, N. Y., and at additional mailing offices. U. S. subscription rate for individuals in the field of publication: $3 per year. Further details p. 6. POSTMASTER: Please send Form 3579 to Fulfillment Manager, Control Engineering, 330 West 42nd Street, New York 36, N. Y.

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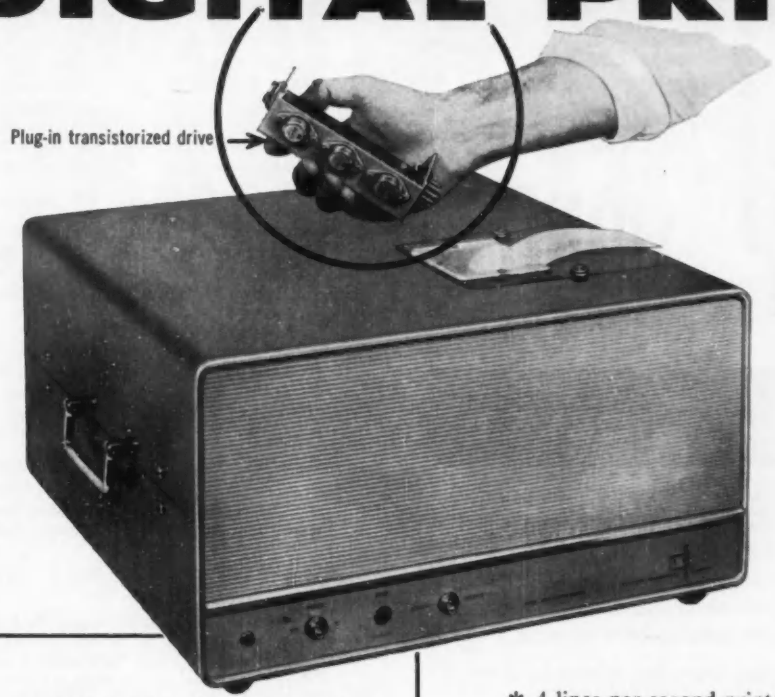

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MAY 1961 VOL. 8 NO. 5

Published for engineers and technical management men responsible for the design, application, and test of automatic control systems.

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PRINT ORDER THIS ISSUE 34,522

Published monthly by McGraw-Hill Publishing Company, Inc. Founder James H. McGraw (1860-1948). EXECUTIVE, EDITORIAL, CIRCULATION, and ADVERTISING OFFICES McGraw-Hill Building, 330 West 42nd Street, New York 36, N. Y. Telephone: LOngacre 4-3000. Teletype: TWX N. Y. 1-1636. Cable address McGRAW-HILL, N. Y.

OFFICERS OF THE PUBLICATIONS DIVISION: Nelson L. Bond, President; Shelton Fisher, Wallace F. Traendly, Senior Vice President; John R. Callaham, Vice President and Editorial Director; Joseph H. Allen, Vice President and Director of Advertising Sales; A. R. Venezian, Vice President and Circulation Coordinator.

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2N1985 2N1984 2N1983	Small signal types for AC and DC amplifiers	TO-5	50 mc	2 watts	15* 35* 70*	45* 100* 210*	40	50	—	—	5 μA
2N1987 2N1986	Switching types	TO-5	50 mc	2 watts	20 60	80 240	40	50	0.9	0.6	5 μA
2N1989 2N1988	High voltage types particularly suited to video amplifiers and RF oscillators	TO-5	50 mc	2 watts	20 35	60 120	60	100	1.0	2.0	5 μA
2N1991	PNP complement to the small signal and switching types	TO-5	50 mc	2 watts	15	60	25	30	—1.5	—1.5	5 μA
2N1990	Neon tube and Nixie® driver type	TO-5	—	2 watts	20	—	60	100	1.0	0.5	—

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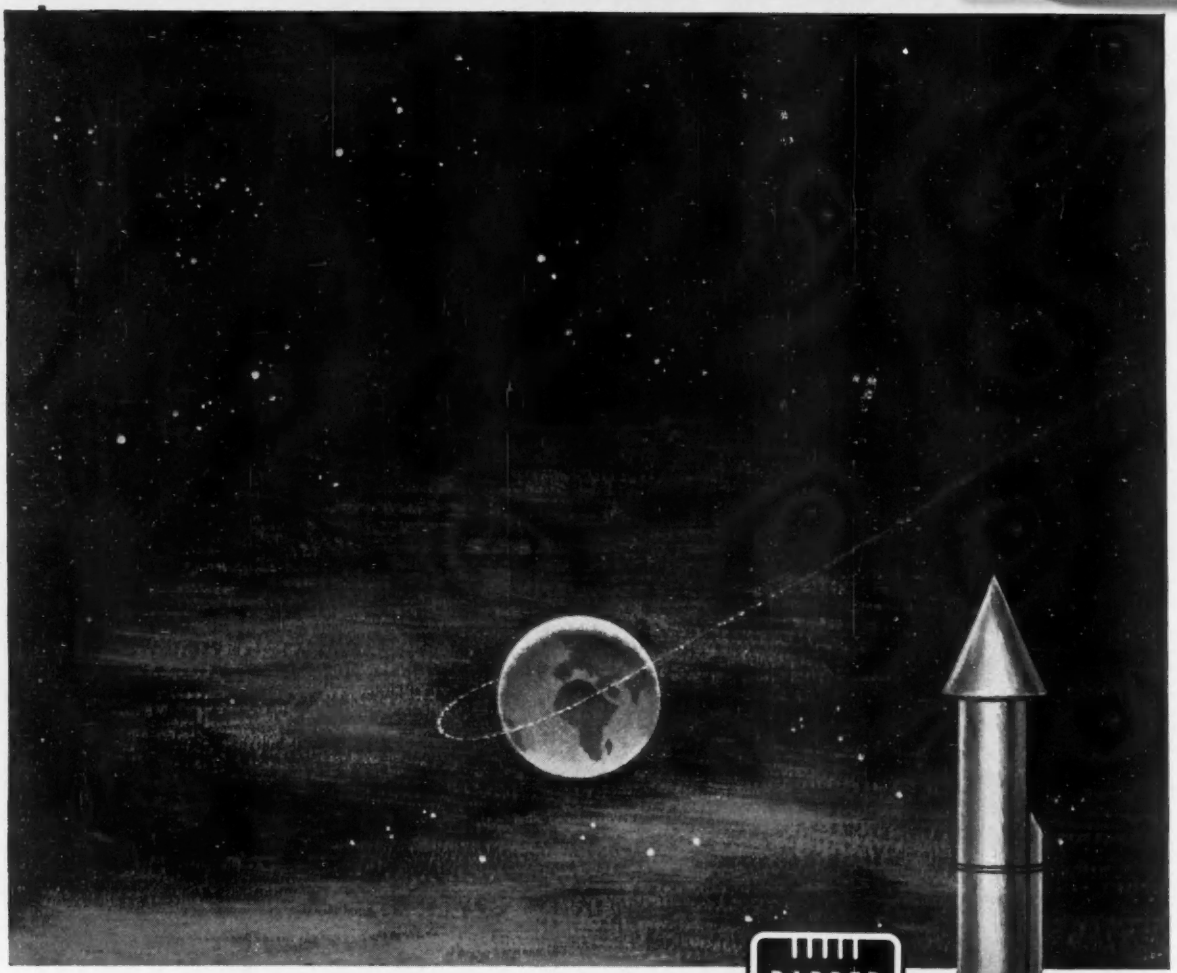

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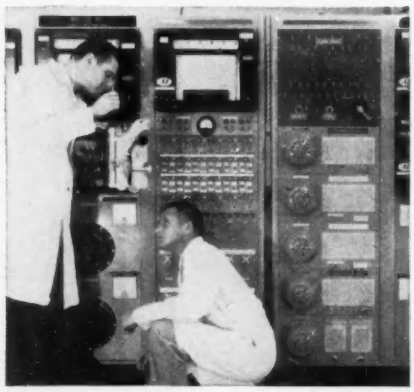

Atomics International, a Division of North American Aviation, Inc., designed this control system at Canoga Park, Cal. for testing nuclear fuels at the National Reactor Testing Station in Idaho. The panels monitor surface and center fuel temperatures and control a neutron absorbent for four fuel capsules simultaneously.

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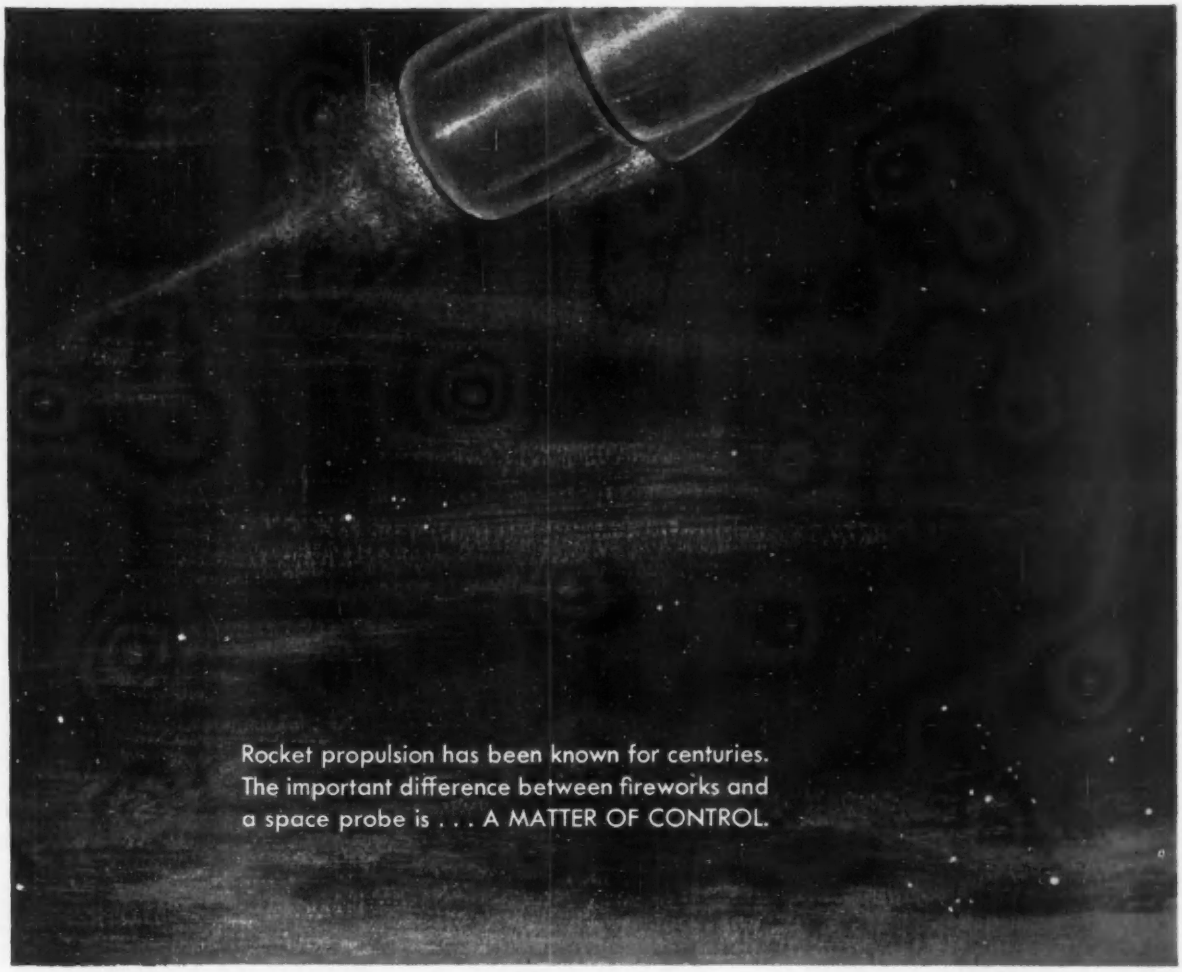
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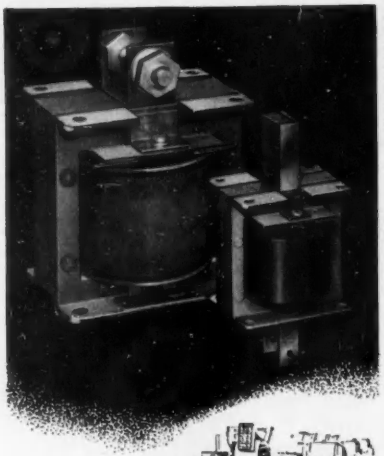

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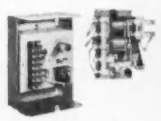

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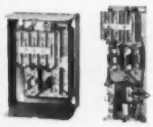

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SHOPTALK

Editors on the rostrum

With a spate of technical meetings coming up this spring, three CONTROL ENGINEERING editors are getting ready to make their interpretive contributions—

- On April 12, Senior Associate Editor Lew Young was keynote speaker at the Fairfield County (Conn.) ISA section's annual program for some 60 high school science and mathematics teachers. Lew's subject: teaching machines.
- On May 10 at Green Bay, Wisconsin, Chief Editor Byron Ledgerwood will address the Instrument Society of American Pulp and Paper Division's second national symposium. Focusing on the instrumentation and control problems facing the paper industry, Byron's talk will outline the personnel, techniques, and facilities needed by the user to bring advanced automatic control systems to his plant. Byron plans to support his views by extrapolating past control successes in other industries having similar problems.
- On June 6 at ISA's Toronto Regional Conference, Managing Editor Harry Karp will participate in the Chemical and Petroleum Division session. Harry's presentation, *Process Management by Control Computers: Tactics and Strategy*, will review some current approaches to control computers and auxiliary instrumentation as one method for improving plant payout and will discuss some existing on-line control computer installations.

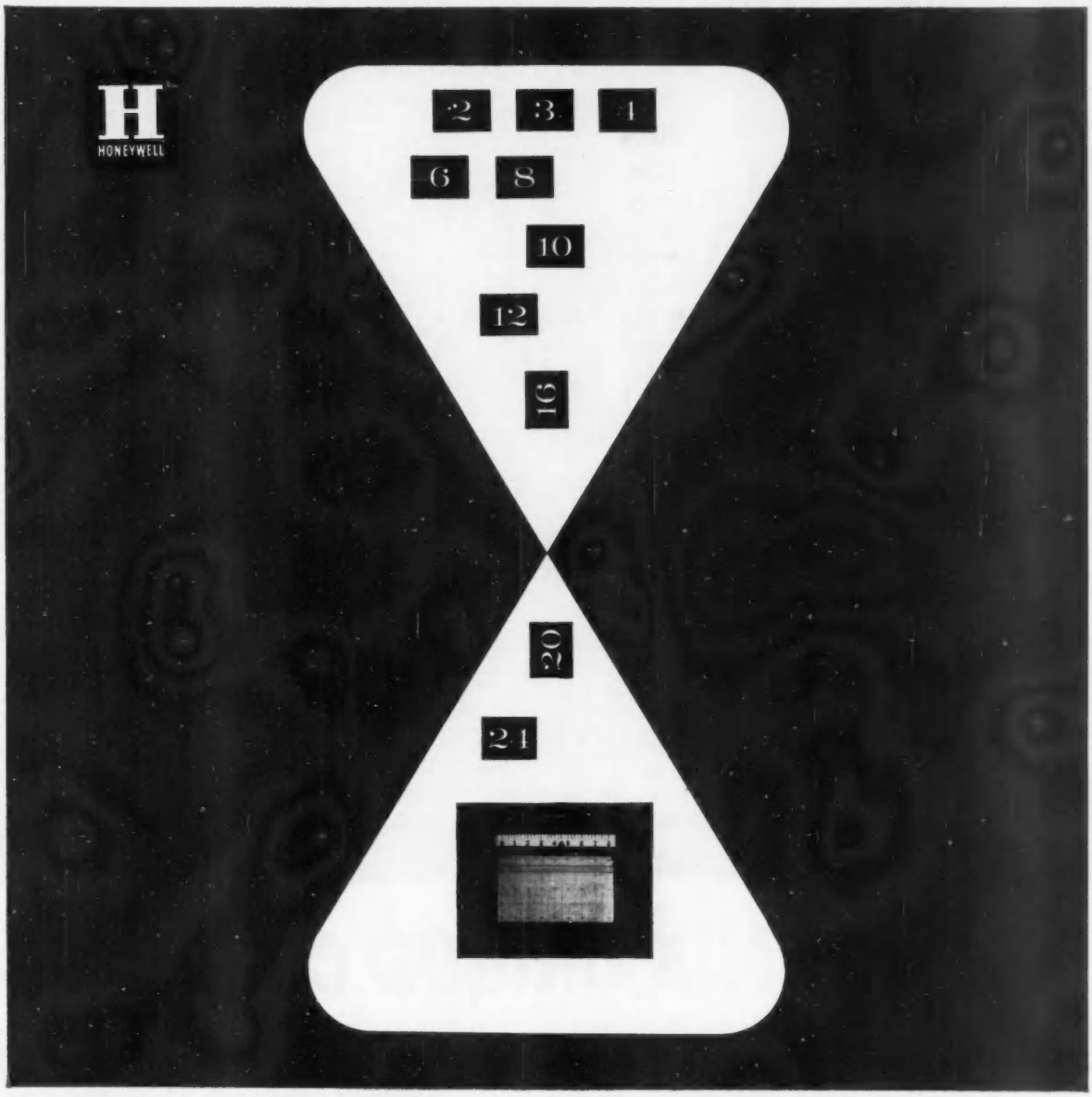
Industrial chromatography survey

Just four or five years ago chromatography as an industrial stream composition analysis technique was a rarity. But even then it held such great promise for success that users and makers alike fostered the infant technique with care. The child has grown into a giant: users can now buy chromatographs for in-plant applications from six manufacturers.

For a comprehensive, staff-written report on industrial chromatographic analyzers, read June CONTROL ENGINEERING. The article will review the basics of the chromatographic technique, describe the major components (and their functions) found in most chromatographs designed for in-plant use, and highlight operation and specific features.

Barlow on BCAC-IFAC for UK

The other day we received a cryptic note—filled with abbreviations like those above—from Derek Barlow, CONTROL ENGINEERING's European editor working out of London. The note was Derek's modest way of letting his Stateside associates know that the British Conference on Automation and Computation nominated him to be the United Kingdom's delegate to the International Federation for Automatic Control's Application Committee. Derek's first task: prepare a report on UK control application in 1960.



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With the new Universal Multipoint ElectroniK 15 Recorder on the job, you'll be able to change the number of recording points from 2 to 3, 4, 6, 8, 10, 12, 16, 20, or 24 in a matter of seconds. With this "quick-change" feature built into it, the new Universal can do the job of 10 recorders!

Conversion is as easy as this—remove thumb nut and slip off old print wheel and indicator dial, slip on new wheel and dial, replace nut, plug in number of points desired and you're ready to go!

If the monitoring jobs in your laboratory, industrial shop, or industrial process require frequent changes in the number of records required, you'll want to get the complete story on the new Universal Multipoint ElectroniK 15 Recorder.

Contact your nearby Honeywell field engineer for full details. Minneapolis-Honeywell, Wayne and Windrim Aves., Phila. 44, Pa. In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell

H First in Control SINCE 1885

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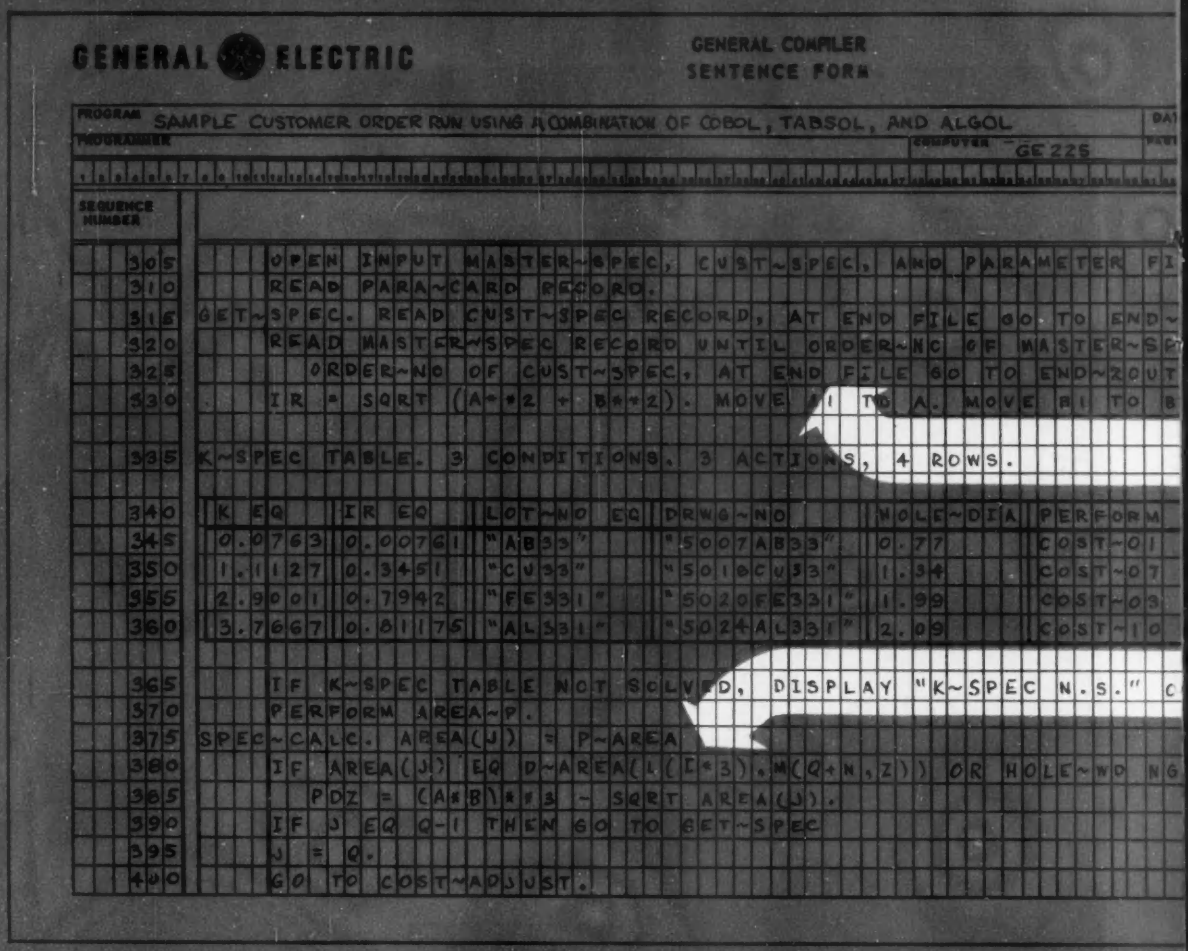

GENERAL ELECTRIC
GENERAL COMPILER
SENTENCE FORM
PROGRAM SAMPLE CUSTOMER ORDER RUN USING A COMBINATION OF COBOL, TABSOL, AND ALGOL
PROGRAMMER
COMPUTER GE 225
SEQUENCE NUMBER
305 OPEN INPUT MASTER~SPEC, CUST~SPEC, AND PARAMETER FI
310 READ PARA~CARD RECORD.
315 GET~SPEC. READ CUST~SPEC RECORD, AT END FILE GO TO END~
320 READ MASTER~SPEC RECORD UNTIL ORDER~NO OF MASTER~SP
325 ORDER~NO OF CUST~SPEC, AT END FILE GO TO END~OUT
330 IR = SQRT (A~*2 + B**2). MOVE A I TO A. MOVE R I TO B
335 K~SPEC TABLE. 3 CONDITIONS. 3 ACTIONS, 4 ROWS.
340 K EQ IR EQ LOT~NO EQ DRWG~NO HOLE~DIA PERFORM
345 0.0763 0.00761 "AB33" "5007AB33" 0.77 COST~01
350 1.1127 0.3451 "CV33" "5016CV33" 1.34 COST~07
355 2.9001 0.7942 "FE331" "5020FE331" 1.99 COST~03
360 3.7667 0.81175 "AL331" "5024AL331" 2.09 COST~10
365 IF K~SPEC TABLE NOT SOLVED, DISPLAY "K~SPEC N.S." C
370 PERFORM AREA~P.
375 SPEC~CALC. AREA(J) = P~AREA
380 IF AREA(J) EQ D~AREA(L([I*3),M(Q+N,Z)) OR HOLE~WD NG
385 PDZ = (A*B)**3 ~ SQRT AREA(J).
390 IF J EQ Q-1 THEN GO TO GET~SPEC
395 J = Q.
400 GO TO COST~ADJUST.

GECOM...A UNIQUE CONCEPT IN

now available in the GE 225 ... and future General Electric general-purpose computers.

- processes COBOL, ALGOL and TABSOL*
- all problem statements easily read and understood
- extended usage... re-programming unnecessary
- programs produced faster... more efficiently

GECOM—the first truly GENERAL COMPILER SYSTEM—introduces a fresh, versatile approach to computer communication. Developed for the GE 225 computer, the GENERAL COMPILER *makes available all of the various proved programming techniques in one consistent, compact package.* No longer is it necessary to learn a dozen different programming systems to handle a full range of jobs effectively—each job is approached in *exactly the same way*, be it formula evaluation, a sort, or even a payroll. The language for describing any run is *consistent*, operating procedures and programming are *standard*, and documentation is readable and easily *understood*.

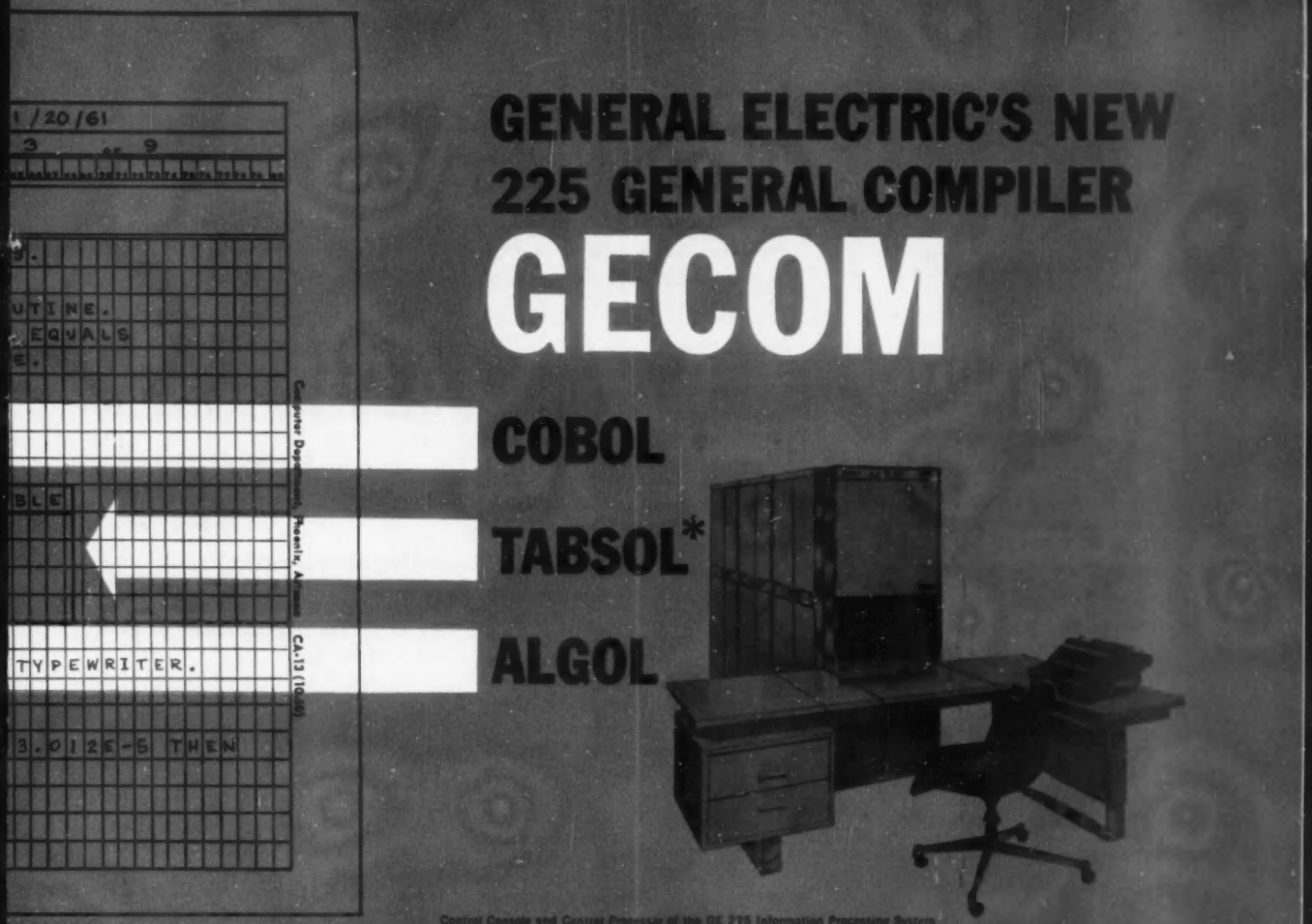
*A General Electric Trademark

THE GENERAL COMPILER PROVIDES—

A FAMILIAR LANGUAGE STRUCTURE—Problems need not be stated in machine code. The GENERAL COMPILER processes English language statements (COBOL), Algebraic expressions (ALGOL), and Structure Tables (TABSOL). It permits you to use all or any one of the computer languages... as your needs require. Still, you have available the capability to expand, use other languages and new techniques as your needs change.

A PROVED, ACCURATE CODER—Data Description and Problem Logic may be written in one, two, or a combination of the available languages producing a machine program of efficient, effective coding. Since the machine coding is derived directly from the logic of the problem statement, it is only at the logic level that debugging may have to be done.

A STANDARDIZED, UNDERSTANDABLE DOCUMENTATION—Because GENERAL COMPILER problems are written in familiar languages, they can be easily read and under-



COMPUTER COMMUNICATION

stood. In addition, problem format provides a high degree of standardization. Programs written for today's machines in GECOM format can be used for future General Electric computers—eliminating the need for re-programming.

AN EFFICIENT, ECONOMICAL USE OF COMPUTERS—Personnel training time and expense are sharply reduced since the novice programmer may use the familiar terminology of his profession. Manual coding is eliminated and debugging cut to a minimum. Thus, a machine program may be produced much faster and more efficiently than by present manual methods.

THE GENERAL COMPILER IS ANOTHER GENERAL ELECTRIC FIRST!

For more detailed information, write today for brochure CPB-144 on the new General Electric General Compiler. Also available: brochure CPB-101 on the GE 225 Information Processing System and CPB-81 on the GE 210 Data Processing System.

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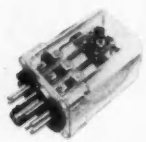
GENERAL PURPOSE Plug-In Type Relay. Contact arrangements up to 3PDT. 5 or 10 amp contact rating. Voltages up to 230 volts, AC or DC. Details in Bulletin 10.



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FEEDBACK

PROBLEM FORUM

An early winner of Problem Forum prize points out the recent appearance of a product that seems to be a commercial version of his suggestion made six years ago in CONTROL ENGINEERING.

To the Editor—

Six years seems a rather long time for your readers to take advantage of the problem solutions you offer.

Perhaps you will be amused, as I am, by the recent appearance of a piece of equipment designed to solve a problem you posed in Vol. 1, No. 4, December 1954, when Control Engineering was a fledgling.

You paid me the magnificent sum of $5.00 for a solution that you published in Vol. 2, No. 2, February 1955. The sludge pump control recently announced by Komline-Sanderson Engineering Corp. certainly sounds like a commercial version of my suggestion. The question is how to reduce the long time interval between suggestion and product.

F. L. Avera
Director of Research—SKIPPY
Best Foods, Div. of Corn Products Co.
Alameda, Calif.

The problem as stated in December 1954 asked for suggestions on how to anticipate viscosity changes in pipelines where, for example, viscous sour asphalt crude is directly followed by low-viscosity sweet crude. To win his prize Reader Avera suggested a nuclear gage across the pipeline to detect the change in product density. The sludge pump control by Komline-Sanderson spots density variations and stops and starts the sludge pump in response to changes in the concentration of solids in line. The device uses a nuclear gage, as the Problem Forum solution did. Maybe the answer is to go into business when you spot a needed product. Ed.

Attention problem solvers

To the Editor—

To maintain register between a cutoff and a continuous web, we are using a cutoff register control with conventional photoelectric scanning of printed register marks. Because of certain adverse scanning conditions inherent in our process, photoelectric scanning is not as effective as we would like it to be.

We believe that the use of magnetic inks and an appropriate pickup to generate and transmit signals to our control might offer many advantages over our present method. We would like to discuss application of equipment or development of new equipment directed toward this problem.

Herman H. Engelhardt
Plant Engineer
Container Corp. of America
Dolton, Illinois

How many want to pick up what appears to be an interesting challenge? Please send a carbon to Feedback Editor so we can relay solutions to all of our readers. Ed.

What's in a name?

With reference to the article, "What's Available in Europe for Electronic Process Control", which appeared on pages 105-108 of the October 1960 issue of Control Engineering, we wish to acknowledge ownership in the United States of the trademark 'TRANSITROL' by Ether Ltd. of Birmingham, England, as evidenced by this company's registration in the U.S. Patent Office on March 5, 1957, under No. 642,327 in respect of instruments for measuring, indicating, and controlling temperature, pressure and flow. Ed.

An unfortunate oversight

To the Editor—

On behalf of Automation Development Corp. we are writing to direct your attention to an apparent oversight in your article "Incremental Servos: Part IV—Today's Hardware", (CtE, March 1961, p. 133).

ADC, a designer and manufacturer of a rather extensive line of step-servo motors, controllers, pulse sources, and power supplies, was somehow not among those present in the review put together by S. J. Bailey.

While we recognize that Mr. Bailey's copy pointed out that his summary did not pretend to list all available hardware, it was strongly implied that products not listed were either: 1) too new for evaluation; or 2) manufacturers had not replied to direct inquiries. While questionnaires were never received directly by ADC, both the author and Control Engineering were made aware of ADC's

Moore Products introduces a new name

SOLID STATE PNEUMATICS

—for an entirely new instrument technology

Today, Moore engineers are working in applied research—with encouraging results—on the use of new operating principles which they call

SSP

For tomorrow, these principles are showing promise for a line of pneumatic process-control and computing instruments which will

—have no moving parts

—have extremely high speed response

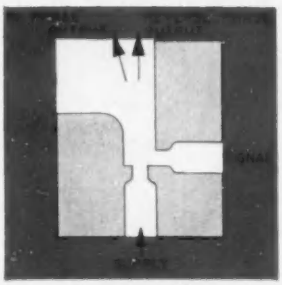
—receive and transmit shock wave signal

—be free of ambient-temperature limitations

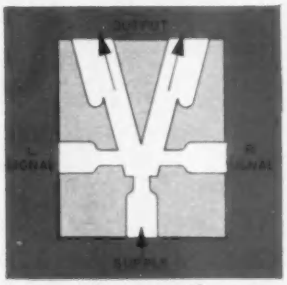
—operate at low or high power levels

—be unaffected by vibration or acceleration

***SSP* is still in the research and development stage. Here are schematic diagrams of a few of the current projects.**



Basic Amplifier

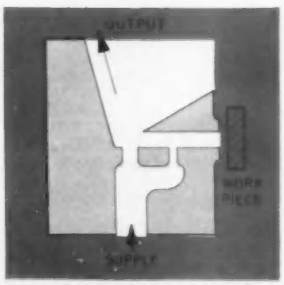


Binary Computer Element with memory

Oscillator

Pulse Counter

Holding-in Relay (positive feedback)



High-speed Dimensional Gaging Switch

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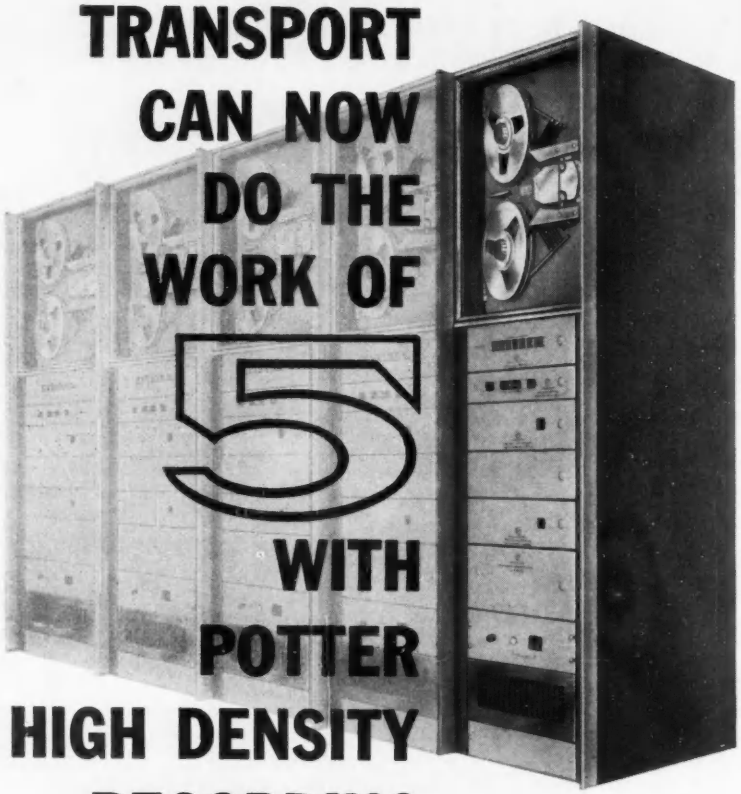
1 TRANSPORT CAN NOW DO THE WORK OF 5 WITH POTTER HIGH DENSITY RECORDING



With the revolutionary new Potter High Density Recording System, one tape transport has the capacity of 5 or more conventional transports.

For highly reliable computer applications, Potter High Density Recording can give you data transfer rates of 360,000 alpha-numeric characters per second, at densities up to 1500 bits per inch on 1-inch tape. Sixteen parallel channels can be accommodated on one-inch tape. Because Potter has made the information channels self-clocking, no separate clock channel is needed, and multichannel data can be read out in true parallel form, despite interchannel time displacement.

In production units delivered by Potter for the BENDIX G-20 COMPUTING SYSTEM at the Carnegie Institute of Technology, this dramatic new technique makes recording so reliable that in 40 hours of continuous operation less than 2 seconds re-read time are required to recover information lost through transient error. Dropouts are fewer than 1 bit in 10 billion at 1100 alpha-numeric characters per inch. More than 20,000 passes of the tape can be made without losing information or significantly increasing the reading error rate.

Tested and proven in computer systems, Potter High Density Recording is presently available in the Potter 906II High Speed Digital Magnetic Tape Handler, and will be available in other Potter Tape Systems.

Write today for details on how High Density Recording can be applied to your data handling problem.

POTTER INSTRUMENT COMPANY, INC. • SUNNYSIDE BOULEVARD, PLAINVIEW, NEW YORK

16 CIRCLE 16 ON READER SERVICE CARD

FEEDBACK

product line and technical competence well in advance. The following information shows that the ADC line of stepping motors would have been among the most complete listed.

The line of Automation Development Corp. stepping motors includes sizes 5, 8, 11, 15, and 23 with corresponding weights of 1.5, 2.0, 6.0, 4.5, and 9.0 oz and corresponding load torques of 0.4, 0.8, 1.8, 1.8, and 3.0 oz-in. All units have the following characteristics: 28-volt dc pulse input; two-phase construction; bidirectional, magnetic detent; 45, 90, 180, or 360 deg/step; and up to 250 steps/sec synchronized and to 800 slewing. Controllers and transmitters are available with all units.

Ted Shields
West Associates
Los Angeles, Calif.

Error in the error

TO THE EDITOR—

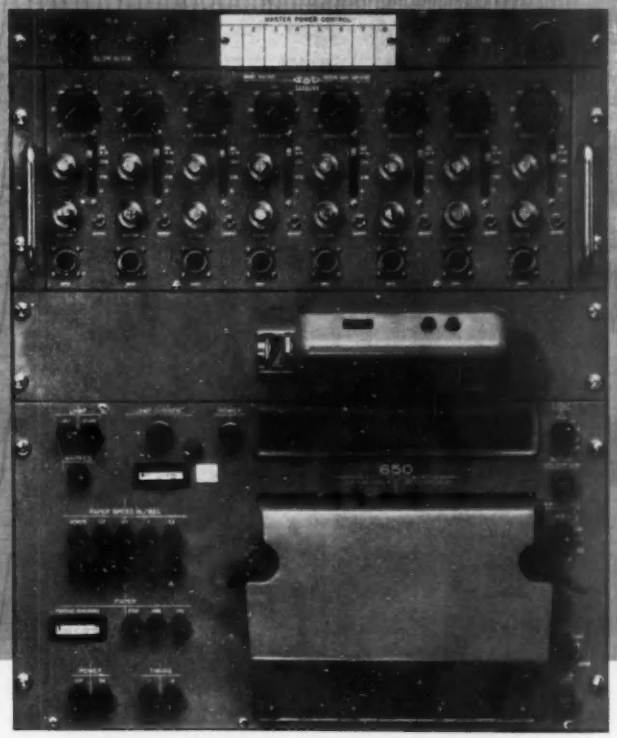
In your report concerning the British Optical Reader (CtE, Jan. 1961, p. 23) one of the reasons quoted for the change of policy by Boots Pure Drug Company in not using the Solartron ERA Optical Reader for analysis of tally rolls received from Boots' branches throughout Britain was "A 10 percent human inaccuracy in making the initial entry". If this were so, British department store users would have been complaining a long time back, as the possibility of such an error would make it impractical to use cash registers as the standard tool for accounting retail transactions. The actual reason for nondelivery was a change in Boots' control accountancy.

The human error figure gathered by your representative and reported in good faith is unfortunately incorrect, the 10 percent error relating to a special test program of 500 blocks, each of 197 characters, that was run through the cash register-Solartron ERA reader system. When prepared by newly trained labor, isolated keying errors occurred in 10 percent of the blocks, representing a key depression error of less than 0.02 percent.

Bowman Scott
Managing Director
Solartron Electronic Business Machines Ltd.
Farnborough, Hants, England

Faulty communications led us astray. The well-known retail cash register would have never gotten off the ground if the stated error were correct. Ed.

DC to 5000 cycles over an amplitude of 4″ peak to peak



NEW SANBORN "650" SYSTEM OFFERS DIRECT READOUT, 8 TO 24 CHANNELS, ALL SOLID STATE CIRCUITS, FOR RACK MOUNTING OR INDIVIDUAL CASES.

Here's the *one* system that lets you record inputs from DC to 5 KC within 3 db at 4″ peak-to-peak amplitudes, without changing galvanometers. The "650" system consists of an 8-channel medium gain, general purpose amplifier unit driving a high speed, high resolution optical oscillographic recorder. It can be easily built into your system, packaged in a mobile cabinet or housed in individual cases. The single-chassis, 7″ high amplifier module has 8 separate channels, *complete from floating and guarded inputs to galvanometer outputs;* each channel comprises a front end modulator and input transformer, carrier amplifier, demodulator, filter and driver amplifier. Power Supply and Master Oscillator Power Amplifier are built-in. All amplifier elements are plug-in transistorized units for easy servicing.

Immediately readable recordings are made on 8″ wide daylight-loading ultra-violet-sensitive charts which require no chemical development. Features of the 12¼″ high recorder unit include 9 electrically controlled chart speeds from ¼″ to 100″/sec; calibrated monitoring screen; automatic trace identification and timing lines at 0.01 or 0.1 sec. intervals; amplitude lines spaced 0.1″ apart which can be blanked from ¼, ½, ¾ or all of chart. Recorder is available with an 8-, 16- or 24-channel galvanometer block which is then equipped with the number of galvanometer elements desired by the customer. Either the Recorder or Amplifier are also available as individual units for use with other equipment.

SENSITIVITY 20 mv input gives 8″ deflection; 12 attenuator steps to X5000, smooth gain control.

INPUT RESISTANCE 100,000 ohms all ranges, floating and guarded; DC source resistance must be kept below 1000 ohms on mv ranges only.

COMMON MODE PERFORMANCE Rejection at least 140 db at DC, tolerance to ±500 volts, max.

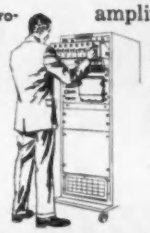
GAIN STABILITY Better than 1% to 50° C. and for line voltage variation from 103 to 127 volts.

LINEARITY 1½% of full scale (8 in.)

NOISE 0.02″ peak-to-peak, max.

MONITOR OUTPUT On front panel; provides ±1v full scale across 100,000 ohm load

POWER REQUIREMENTS 103-127 volts, 60 cycle AC, 625 watts



Contact your Sanborn Sales-Engineering Representative for complete specifications and applications engineering assistance. Offices throughout the U. S., Canada and foreign countries.

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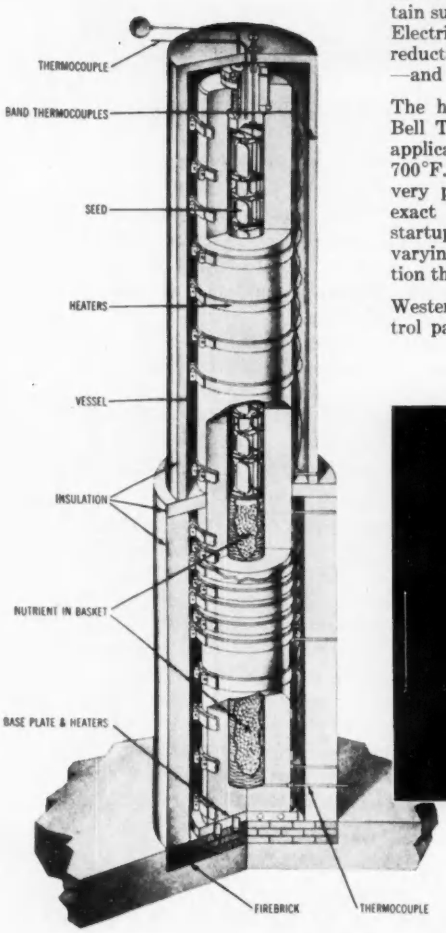
Western Electric's Fabulous Quartz Crystal "Factory"...

UNDER FULLY AUTOMATIC *Taylor* ELECTRONIC CONTROL



The Western Electric Company, at their Merrimack Valley works, North Andover, Mass. is the world's first quantity producer of artificially "grown" quartz crystals. Developed to meet the fast growing needs of the Bell System, and to offset the uncertain supply of natural quartz, the Western Electric process produces crystals at a reduction in the cost of the natural variety —and with fewer imperfections.

The hydrothermal process developed by Bell Telephone Laboratories requires the application of about 25,000 psi pressure at 700°F. within an autoclave. It demands very precise control of temperature and exact temperature differentials during startup. Also extremely accurate and unvarying temperatures and pressure regulation throughout a 21 day "growing" period.

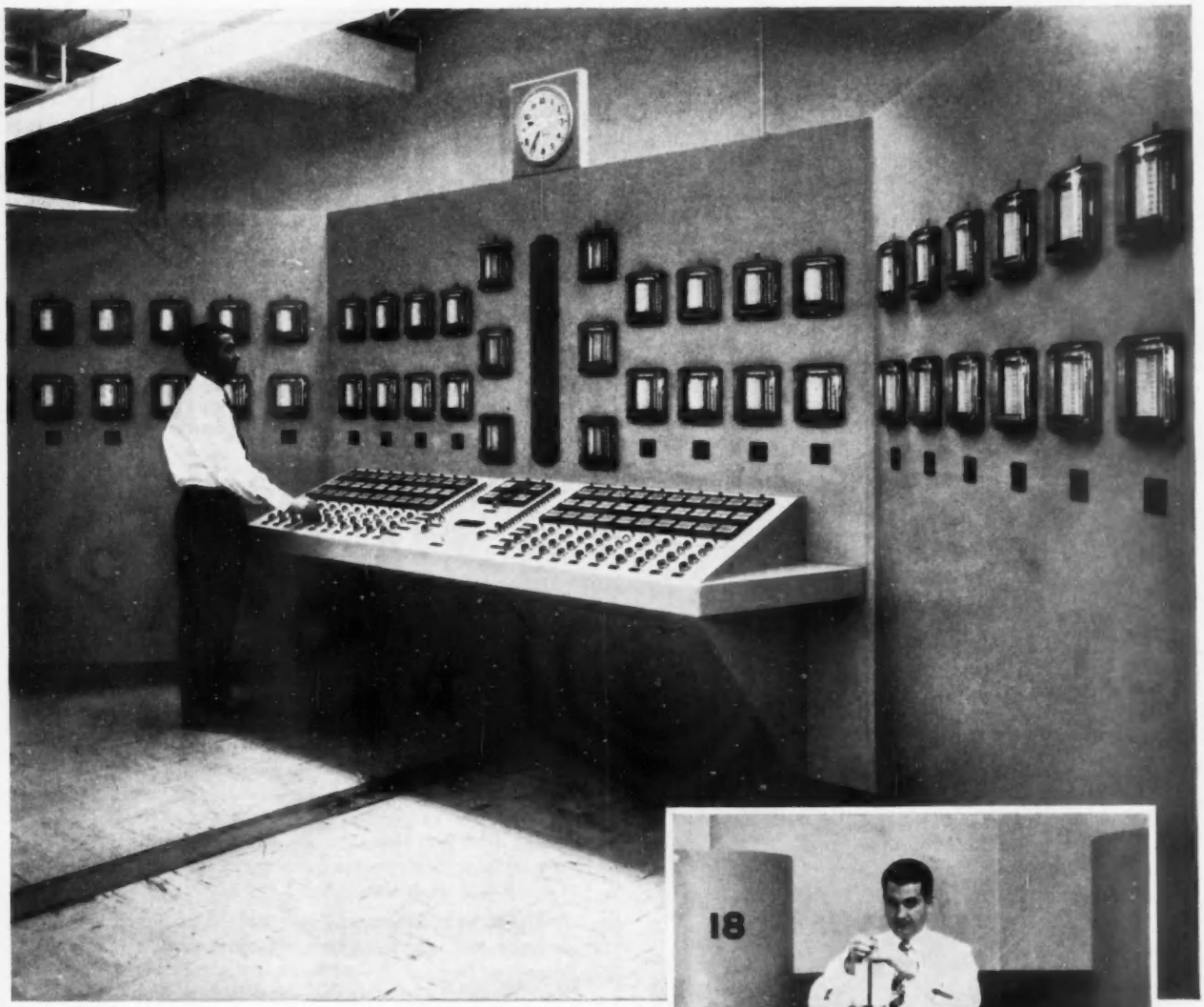
Western Electric engineers set up the control parameters, time program and tolerances necessary; Taylor Instrument Companies designed the electronic control system—completely automatic aside from loading and unloading. Safety instrumentation, also provided by Taylor, is so reliable that the entire crystal growing building is left unattended except during the day shift.

TRANSCOPE* electronic instruments met two major requirements for this application. Uninterrupted control is assured by the use of premium quality components. Overpeaking at the beginning of the growing period is eliminated by the unique design features of the controller which includes a diode limiter circuit. We are proud to have played a part in this outstanding achievement of Western Electric Company.

Taylor Instrument Companies, Rochester, N.Y., and Toronto, Ontario.

*Reg. U.S. Pat. Off.

Taylor Instruments



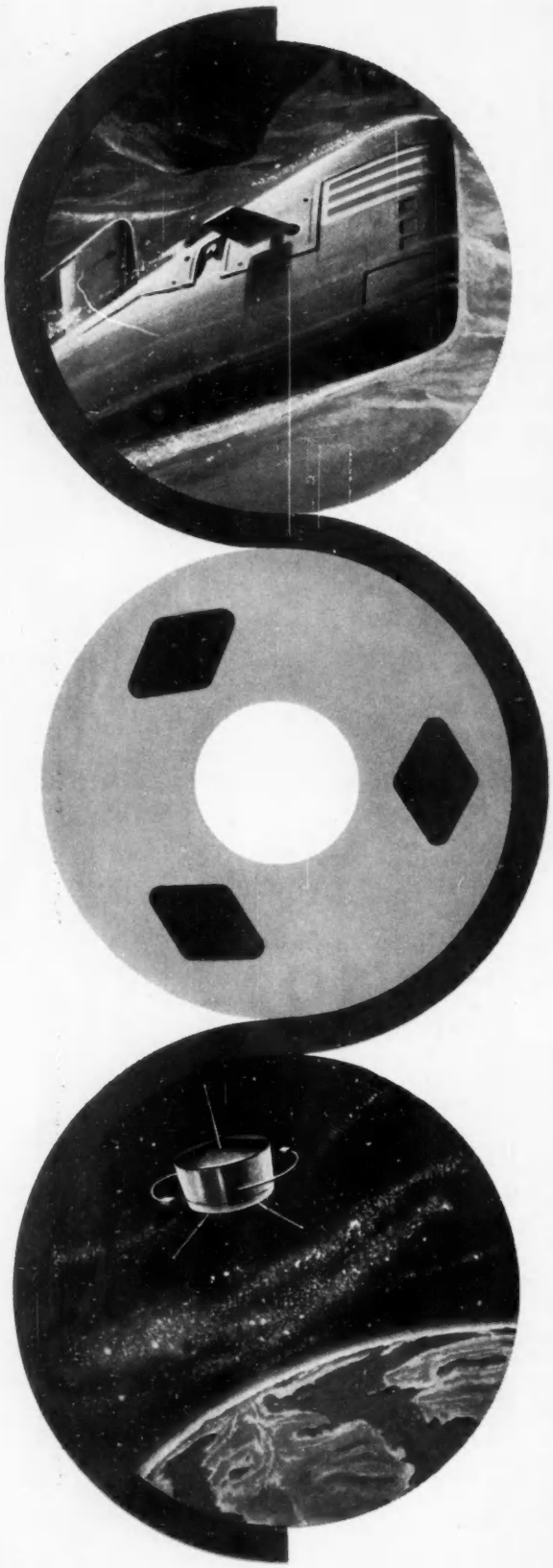
Coals to Newcastle— Western Electric, manufacturing unit of the Bell Telephone System, chose Taylor Electronic Controls for this critical process. Central control panel (above) shows two sets of "warm-up period" recorder-controllers in center (vertical rows of three each), and ten pairs of "growth period" recorder-controllers on either side. Beneath each pair is a digital counter showing duration of growth period in 10ths of days.

Right—Seed plates being lowered into the autoclave for the 21 days growth.

Left—A harvest of sparkling crystals . . . with none of the imperfections usually found in natural quartz.

Far Left—Cross section of one of 20 autoclaves. Process depends on the maintenance of a critical temperature differential between the nutrient area (lower zone) and the seed plate area (upper zone). Nutrient—low grade quartz—dissolves in hotter lower zone and is carried by convection to the cooler, upper seed chamber where it deposits onto seed plates in a single crystal form.

MEAN ACCURACY FIRST



SOUNDCRAFT INSTRUMENTATION TAPE IN SPACE AND UNDERSEA WITH TIROS II* AND THE SEA DRAGON

The Tape Selected For The Video System In Tiros II! Orbiting with the Tiros Weather Satellite II, developed by RCA for the National Aeronautics and Space Administration, Soundcraft Tape is used exclusively in both narrow and wide angle video tape systems. Only ⅜ of an inch wide, this tape records longitudinally rather than across the width and is the result of over five years of research.

On The Nuclear Submarine, Sea Dragon, the first undersea magnetic video tape recorders also developed by RCA, used Soundcraft instrumentation tapes to record and store data on under-ice characteristics of icebergs and ice flows. As man probes deeper and deeper into the unknown, science continues to call on the world's most modern tape plant for reliable magnetic tapes.

Discover how Soundcraft's consistent record of accomplishment can be extended and applied to fulfill your recording needs. Write for complete literature.

*Soundcraft Instrumentation Tape is, of course, used in Tiros I, and in other vital space projects as well.

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R-131

J. A. Aseltine

what after adaptive control?

In Dr. John Arthur Aseltine's office, if you close your eyes when you listen to his slow thoughtful drawl, you can picture a methodical college professor eased back in his chair with hands twined behind his head. But open your eyes and the illusion is gone. Since his days in college John Aseltine has been a man "on the go". At 36, he is director of sensing and information sciences for the recently formed Aerospace Corp., the non-profit successor to Space Technology Laboratories in Air Force Weapons Systems Management. His job—responsibility for space weapons systems planning and preliminary design in the areas of guidance, control, communications, computers, and ground environment—keeps him traveling around the country visiting Air Force research facilities and contractors.

From his position as control system manager, Aseltine sees a broad perspective of the control field. His concentration on space vehicle control keeps him posted on subject matter that borders the frontier of new technology. And one of his pet subjects is the adaptive system.

Since 1958 when he coauthored three important papers on adaptive control, Aseltine has been caught up by the spell of control systems that can change their own characteristics. Most recently he's forsaken their design to focus on where such systems can be applied fruitfully. His conclusion: use the adaptive principle when the characteristics of the device or system to be controlled are known so imperfectly that the control system has to measure performance and adjust the controller continually.

"This kind of control", he says, "requires equipment sophistication beyond the fixed controller or the preprogram controller which changes with varying conditions or time. It would be called an adaptive controller if it based its whole characteristics on measurements of the system being controlled".

The adaptive controller is not a panacea, as Aseltine sees it. "When you consider building the degree of sophistication that adaptive control implies, you have to be ready to incorporate nonlinear systems that can be difficult to understand and to design. You also have to decide how additional components and complexity will affect reliability of the system. That means you have to look very carefully at a problem before taking the adaptive route; the adaptive concept requires full justification."

Aseltine's view has been shaped by some hard practical experience on a variety of missile programs. He has contributed to primary electronic guidance and control systems for such "birds" as Falcon, Polaris, Titan, Thor, and Atlas.

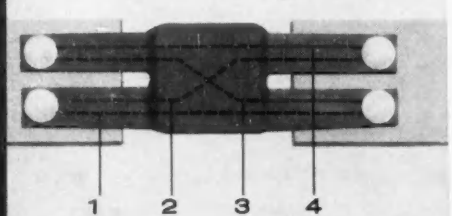
One of that rare breed, a native Californian, John received all his academic training at the University of California. In 1947, he received a BA degree, majoring in physics on the campus at Berkeley; in 1949, a MS degree in engineering; and in 1952, a PhD degree in engineering, the latter two at UCLA.

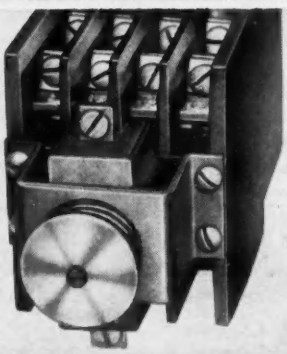
Despite an 11-hour day at Aerospace Corp., he manages to cram in a barrelful of professional activities, to publish papers, and to teach a class in control system theory at UCLA. Here is just a partial list of his present outside activities: member of the Control Theory Committee of the American Automatic Control Council; executive editor for the United States of *Automatica*, an international journal, automatic control and automation; member of the Nonlinear Feedback Control Systems Subcommittee of the American Institute of Electrical Engineers; secretary of the Administrative Committee, Professional Group on Automatic Control, Institute of Radio Engineers; member of subcommittee on optimal and adaptive systems for the U.S. of the International Federation of Automatic Control.

For today and tomorrow's control theory, Aseltine has set his sights on topics that are outgrowths of his interest in adaptive control. One is optimal control, through the approach propounded by R. E. Bellman of the Rand Corp. and the Russian Pontryagin. Another entails prediction, identification, and definition of control system performance criteria—key factors in analyzing and designing the sophisticated controls that are the core of John Aseltine's professional elan.

Another Cutler-Hammer first! Up to 24 poles in an area less than the size of a dollar bill.

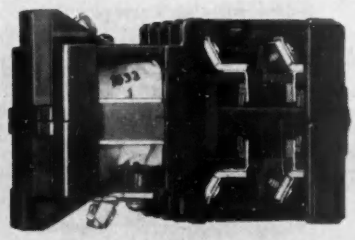
New contact reliability. Parallel bifurcated contacts, which allow four current paths instead of one, provide infinitely greater circuit reliability . . . liberally designed so any current path carries full relay rating.





At last! "Mechanical memory" latch as reliable as the relay itself! No adjustment ever needed. Add latch at any time.

New simplified design! Cutaway view shows basic simplicity. Coil vacuum impregnated to resist damage from humidity, vibration, electrical stress. Terminals can be screw or spade type.



Space savingest relay you've ever seen: New Cutler-Hammer "Compact 300"

Versatile 300 V. control relay is so reliable it's permanently sealed!

Here is the best answer yet to the need for an extremely reliable, small-size 300 V. industrial relay—the new Cutler-Hammer "Compact 300."

Every detail known that affects relay reliability has been improved in the "Compact 300." Bifurcated contacts which make possible *four* current paths rather than one, add millions of operations to the "Compact 300's" electrical reliability.

In fact, we're so confident of its electromechanical reliability, we permanently enclose the "Compact 300." And, if it should be damaged by a fault current, you throw it away and replace it with a new one. Its low price makes this an economical, practical maintenance procedure.

Now think of the space you can save with the "Compact 300." It controls up to eight circuits in panel space only 2″ wide by 2¾″ high. 2, 3, 4, 6 and 8 poles with any combination of N.O. or N.C. contacts are available, of course.

At any time, you can add "mechanical memory" latch with a life equal to the life of the relay. No adjustments are ever necessary. It's another exclusive! Better get full details on the new "Compact 300" now. Send for Pub. ED-L079-S227.

What's new at Cutler-Hammer? New, better products, like the 300 V. relay are coming steadily from our new, expanded plant facilities. We're ready now to help you take care of the great industrial growth of the future. If you are planning ahead and need electrical control assistance, contact the nearest Cutler-Hammer sales office.

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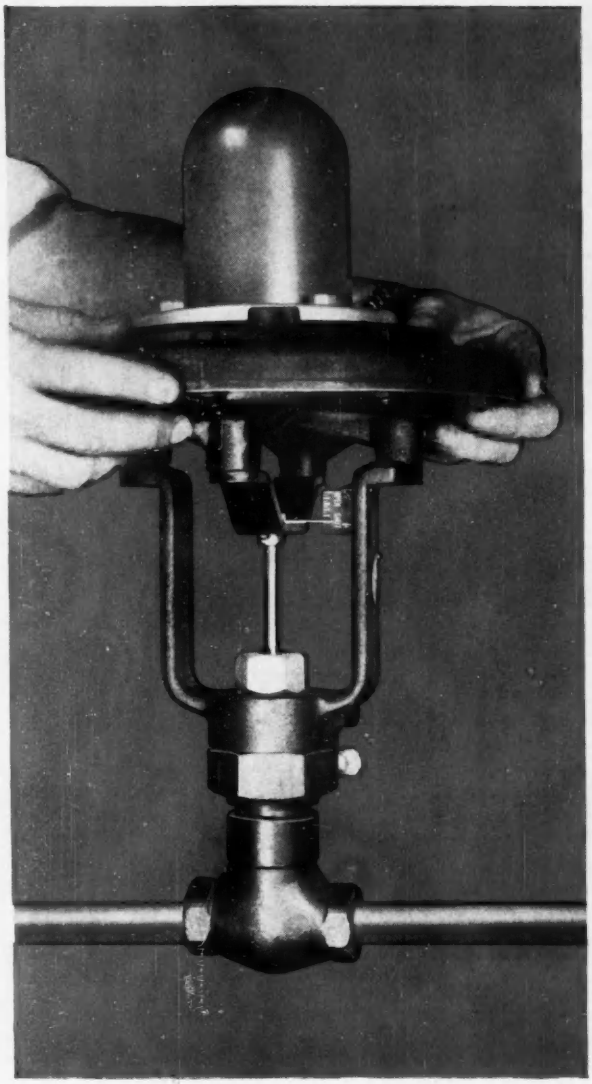

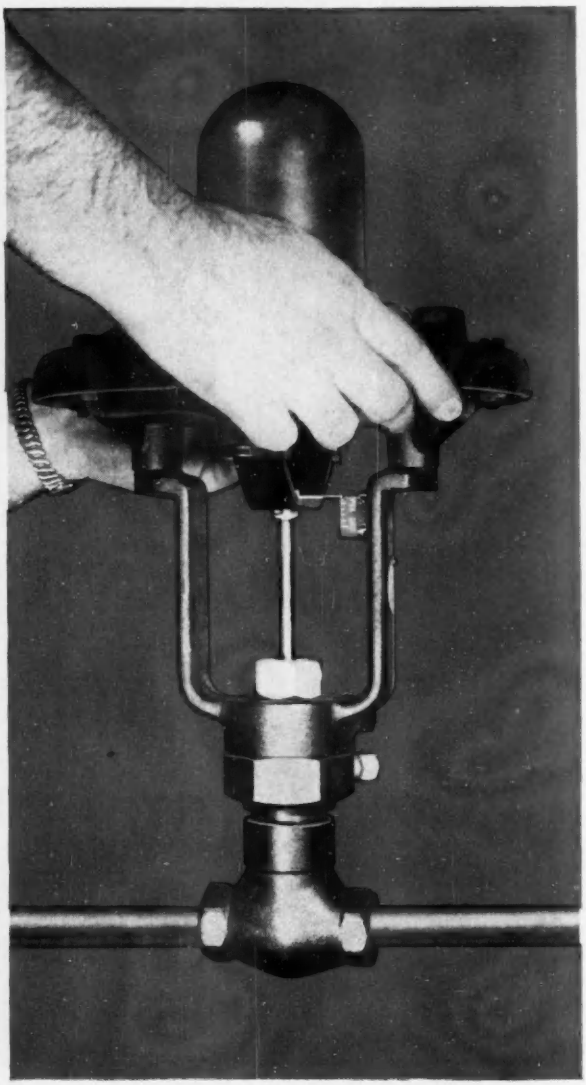

LOOK HOW EASY IT IS TO REVERSE THE ACTION OF A FOXBORO CONTROL VALVE!

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Unbolt the motor casing and rotate it 90°; rebolt and shift air connections — that's all you do to reverse the operation of a Foxboro control valve. Takes just a few minutes — without touching valve body or process piping — without employing special tools or skills.

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Foxboro control valves with their quick-reversible valve motor, are an exclusive Foxboro development. They're perfect for pilot plant operations and other processes frequently "juggled." Types and materials to meet any process requirement.

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Newsbreaks In Control

Rebirth for Automatic Warehousing Machine

Los Angeles—Gertrude, the computer-controlled automatic warehousing machine (CtE, Mar. '58, p. 20), will be installed at a second drug warehouse. Although the first installation at Brunswig Drug Co. was a technical success, the machine never proved economical because of a change in marketing pattern which developed after construction had started. Industrial Electronic Engineers developed the device.

Radiation Effect on Automatic Controls

Dallas—Chance Vought has subjected 24 automatic control system circuits to nuclear radiation doses higher than they would encounter in nuclear-powered aircraft or missiles—about 5×10^{16} neutrons per square cm. Four circuits failed in the radiation. One, a transistorized control system, stopped functioning, as expected, at a dosage of about 10^{12} neutrons per square cm. Many components were discolored, distorted or changed significantly. Some that failed: a ceramic tube modulator and two motor driven amplifiers.

Components in Russian Moon Probe

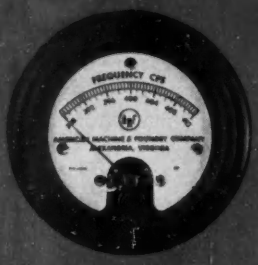
Moscow—The Russian magazine *Ekonomicheskaya Gazeta* has published the first description of the control equipment in the lunar probe that photographed the dark side of the moon. The magazine reported that the probe carried both optical and gyroscopic units, electronic logic devices, and jet motors to stop the vehicle's spinning so the photographic apparatus would have a 40 minute uninterrupted look at the moon. A photoelement continually focused on the sun for vehicle orientation; a simple data system then decided when to fire the rockets.

Little Gypsy on Line

New Orleans, La.—Louisiana Power and Light Company's new steam-electric generating station called Little Gypsy has gone on line. Eventually the 230,000 kw plant will be completely computer-controlled by a Daystrom Information Systems machine. But it will be six months before computer assumes complete control. At present the digital machine is only monitoring performance.

Dutch Fire Control Discovered

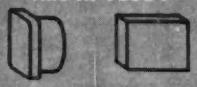
Amsterdam—Hollandsche Signaal Apparatenfabricken has developed a radar firing control system that can aim guns or missiles. And the system has the capability of continuing to search while it is locked onto targets. One other unusual feature: the system will defend against low-flying aircraft as well as high-flying vehicles. Existence of the system leaked out last month when two spies were caught; design started 10 years ago.



Model PFM 400B—90° Scale

switchboard style METERS

MIL-M-16034

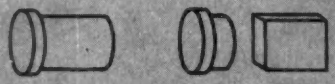


separate sensor

Model PVM 120A—250° Scale

90° panel style METERS

MIL-M-10304

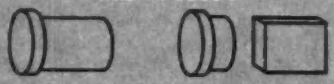


monopak separate sensor

Model PFM 400E4—250° Scale

250° panel style METERS

MIL-M-10304



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PFM 5060 M	PFM 5060 S	48- 53 57- 62	.1	0.2% at 25°C 0.5% from —55°C to +55°C	105-135	Panel	250°	3½"	$220.00
PFM 60B M	PFM 60B S	58- 62	.1	0.1% at 25°C 0.25% from —55°C to +55°C	105-135	Panel	90°	3½"	180.00
PFM 60D M	PFM 60D S	57- 63	.2	0.1% at 25°C 0.25% from 0°C to +65°C	105-135	Panel	90°	3½"	180.00
PFM 60E M	PFM 60E S	55- 65	.2	0.2% at 25°C 0.5% from —55°C to +55°C	105-135	Panel	90°	3½"	180.00
	PFM 400AK S	390-410 300-500	.5 5.0	0.1% at 25°C 0.25% from —55°C to +55°C 1.0% at 25°C 2.50% from —55°C to +55°C	105-135	Panel	dual 90°	3½"	245.00
PFM 400B M	PFM 400B S	388-412	.5	0.1% at 25°C 0.25% from —55°C to +55°C	105-135	Panel	90°	3½"	170.00
	PFM 400B2 S	388-412	.5	0.1% at 25°C 0.50% from —55°C to +55°C	105-135	Panel	90°	2½"	185.00
PFM 400D M	PFM 400D S	380-420	1.0	0.1% at 25°C 0.25% from —55°C to +55°C	105-135	Panel	90°	3½"	170.00
PFM 400E M N		395-405	.2	0.05% at 45°C 0.1% from 0°C to +65°C	105-135	Panel	90°	3½"	235.00
PFM 400EI M	PFM 400 EI S	395-405	.2	0.1% at 25°C 0.25% from —55°C to +55°C	105-135	Panel	90°	3½"	215.00
	PFM 400E4 S	395-405	.1	0.05% at 25°C 0.1% from 0°C to +65°C	105-135	Switchboard	250°	4½"	320.00
	PFM 400H S	380-420	1.0	0.2% at 25°C	105-135	Comm. rectangular	100°	4½"	105.00
	PFM 400HR S	380-420	1.0	0.2% at 25°C	105-135	Comm. round	90°	3½"	115.00

PRECISION VOLTMETERS

MODEL NO. Monopak	MODEL NO. Separate Sensor	SCALE RANGE Volts RMS	RESOLUTION Volts	CENTER SCALE ACCURACY	INPUT RANGE cps	INDICATOR Style	SCALE	METER Size	LIST Price
PVM 115A M N		110-120	0.1	0.1% at 45°C 0.2% from 0°C to +65°C	395-405	Panel	250°	3½"	$250.00
PVM 115AI M	PVM 115AI S	110-120	0.1	0.1% at 25°C 0.2% from —55°C to +55°C	395-405	Panel	250°	3½"	230.00
	PVM 115A4 S	110-120	0.1	0.1% at 45°C 0.2% from 0°C to +65°C	395-405	Switchboard	250°	4½"	335.00
PVM 120A M N		115-125	0.1	0.1% at 45°C 0.2% from 0°C to +65°C	395-405	Panel	250°	3½"	250.00
PVM 120AI M	PVM 120AI S	115-125	0.1	0.1% at 25°C 0.2% from —55°C to +55°C	395-405	Panel	250°	3½"	230.00
	PVM 120A4 S	115-125	0.1	0.1% at 45°C 0.2% from 0°C to +65°C	395-405	Switchboard	250°	4½"	335.00

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Delays Plague Computing Control Start-Up

HUNTINGTON BEACH, CALIF.—

Southern California Edison and General Electric have run into technical snags that have delayed the startup of closed-loop computing control here. Two GE 312 computers are involved, each is to automatically start up and shut down a 210,000-kw turbine generator unit, monitor the operations of major steam apparatus, scan a flock of variables such as pressures, water levels, and temperature flows, and determine if the generator is operating at maximum efficiency.

In the difficulties at Huntington Beach, there are some lessons for both users and makers of computing control. Trouble started when the computers were delivered late. The utility planned that its new units would go on line in November 1960, and they were started up on schedule—without the computers which had failed to arrive. As a result, supplier GE has been forced to do the adjusting and trouble-shooting necessary with any new complex installation on weekends when the plant is not required for generation.

Major technical problems have been in three areas: memory capacity, isolation relay matrix design, and sensor circuit noise. Huntington Beach is not the first facility to run into the memory problem; rumors say both TRW Computers and Daystrom had insufficient memory in their first installations. Sensor circuit noise is another headache that has popped up before. Apparently noise suppression circuits in the GE design were not adequate and have had to be redesigned.

GE engineers told CtE: "The control of large blocks of power by use of largely solid-state devices which have inherently low-power handling capabilities required special consideration. Design refinements were found to be advantageous for isolation and protection of computer control output contacts and to prevent unintentional paralleling of plant control circuits.

"Electrical noise and grounding have been problems in the input circuits involving thermocouples and other low-level input signals. These problems are not so extensive that they cannot be analyzed and corrected.

"Original estimates of the memory capacity required to store the program for fully automated operation of the steam generating plant was considerably less than the actual memory requirements. The actual requirements slightly exceed the capacity of the existing memory system which will be expanded to provide for this excess and added spare capacity for possible future additions to the automation program.

"Furthermore, some program refinements are being made to account for differences between the actual operating characteristics of other pioneering pieces of plant equipment and the characteristics programmed during the plant design stages."

GE now expects the computer installation to be checked out and on line by the end of May.

Bilingual Converter for Japanese Data Processor

ALBERTSON, N.Y.—

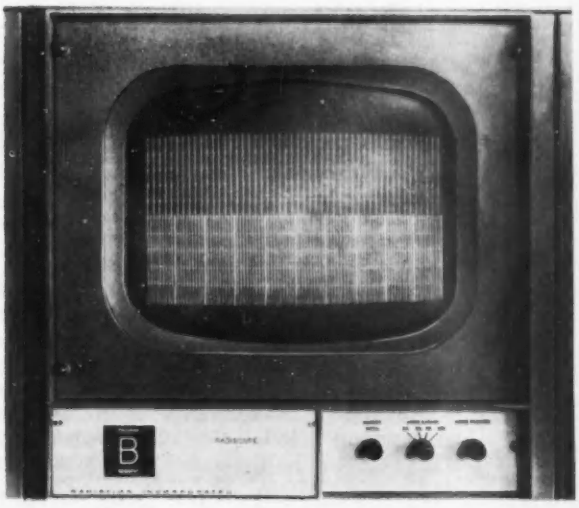
Digitronics Corp. has built two bilingual converters that take data from perforated paper tape and put it on magnetic tape, or from magnetic tape to punched paper tape, at high speeds. The devices, for a Univac computer installation at Tokyo Electric Power, Inc., can handle information in both English and Japanese. Normally a conventional converter provides for an alphabet of 26 characters; the Tokyo Electric equipment has to handle 96.

Primary use of the equipment is to receive information from Japanese teletype lines and convert it to input for the computer. And it takes a computer output on magnetic tape and converts it to punched paper tape for teletype transmission.

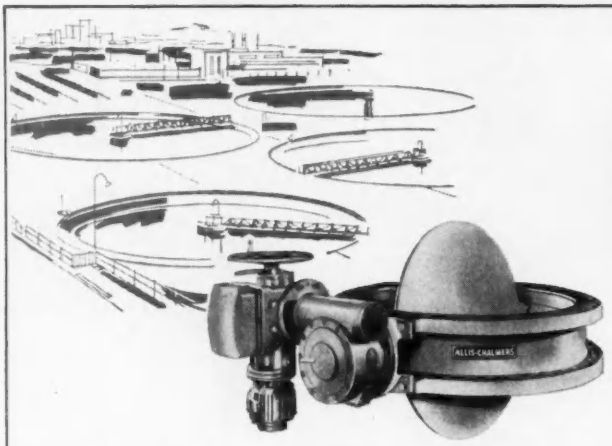
Raster Display for Minuteman Test

MELBOURNE, FLA.—

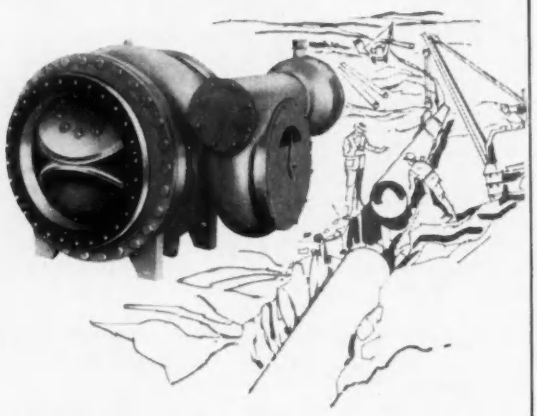
With the television tube display at right, missile testers at Cape Canaveral will be able to watch 100 different parameters during a countdown for Minuteman experimental firings. Radiation Inc. has built four such units to make up a system whose capacity is 400 variables. The raster display receives analog measurements such as temperatures and pressures, converts them to an 8-bit binary digital code, then reconverts them to the bar graph form in which they are viewed. A measurement is converted to a vertical bar proportional to the value of the function to an accuracy better than plus or minus one percent of full scale. Such a display will be most useful in presenting profiles of temperature or pressure, although it can be used to portray individual parameters. In this latter application, only a few variables appear on the screen at any one time. Incoming data are received by the system at a rate of 12,800 points per sec.



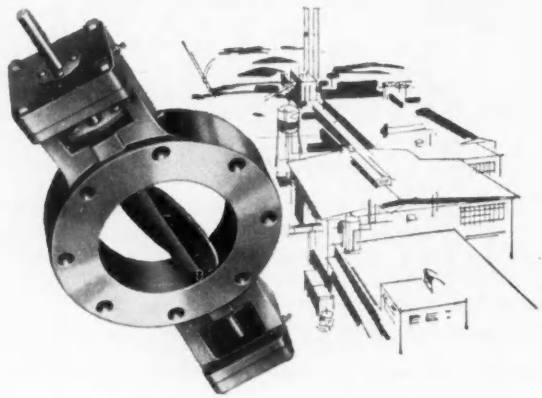
ALLIS-CHALMERS



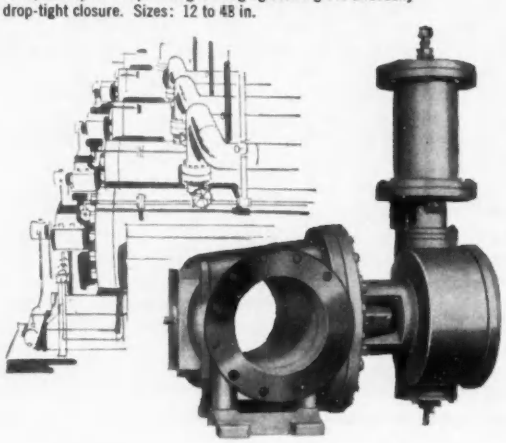
BUTTERFLY VALVES — For liquids or gases — uniform control in all positions, fast positive regulation and closure, minimum pressure drop. Compact and lightweight. Sizes from 1 in.



BALL VALVES — Easy manual shutoff under adverse conditions, and up to 150 psi. Slight wedging action gives unusually drop-tight closure. Sizes: 12 to 48 in.



WAFER VALVES — A new design of butterfly valves with space-saving flexibility, suited to most any type of operation. Sizes from 3 to 36 in., including high-pressure types.



ROTOVALVE — A cone valve suited to virtually any type of operation or location. Offers the least pressure loss, greatest initial shutoff, controlled closing time, positive seating.

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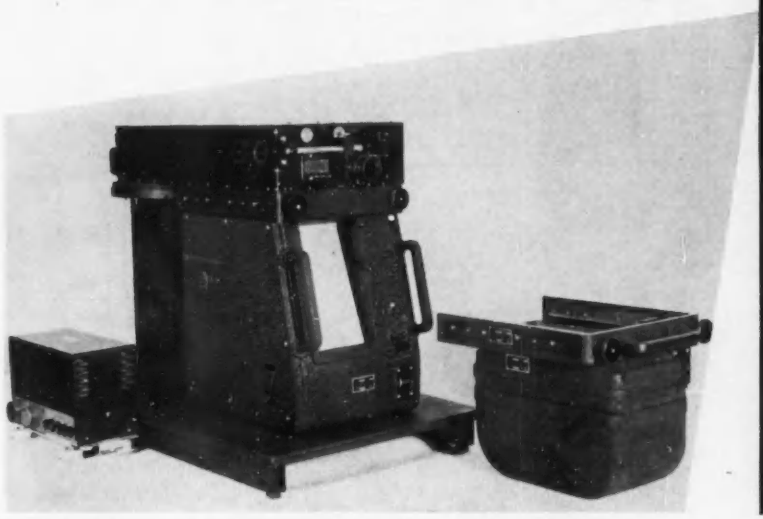
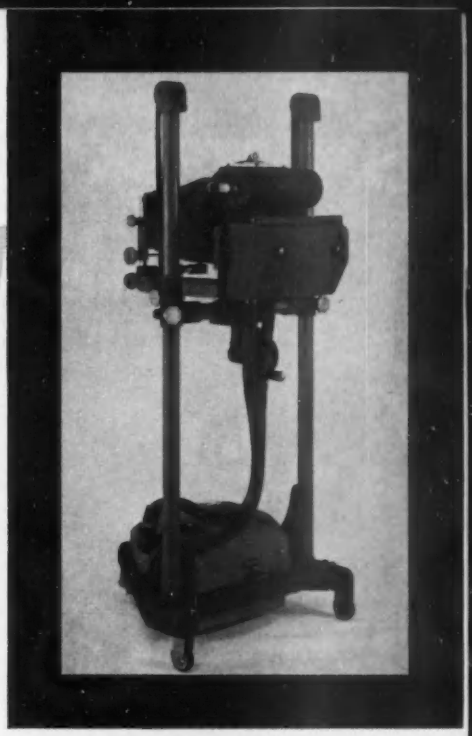
A-1381

From military aerial camera . . .

To industrial data recorder



Typical military aerial camera with rapid processing attachment. Price: over $20,000.



First commercial installation can spew out negatives, positives, or both. Price: under $10,000.

Military Rapid Processing To Make Industrial Data Debut

A technique for rapid development of film in aerial cameras will soon debut for industrial data handling applications. Despite a development time of only 5 sec., the process produces high resolution results precise enough to serve as a data input.

BINGHAMTON—

A high resolution photographic processing system, perfected for aerial radar cameras, will soon be available for commercial data handling and cathode ray tube recording, cutting film development time from a minimum of 12 min to 5 sec. Developed by the Ansco Division of General Aniline and Film Corp., the process relies on conventional photographic chemistry—the conversion of silver halides salts struck by light to metallic silver—but requires a special film sensitive to the blue light of cathode ray tubes, and uses special developing solutions.

When Air Force intelligence men first listened to proposals for taking aerial pictures with radar instead of a lens camera, the reconnaissance experts were not overly enthusiastic. Although electronic mapmaking offered some attractive possibilities, intelligence officers visualized some additional problems, primarily how the plane's crew could see what they were actually getting with the radar beams since the immediate output would be electronic. As a result, the Air Force injected an added specification for radar reconnaissance: the system had to supply crew members with some form of photograph they could read during a mission. The results: first, special film sensitive to the line scan presentation of a radarscope and then rapid processing methods.

• **Sloshing and temperature**—Rapid photographic processing in an airplane introduced some unexpected problems such as how to keep developing solutions from sloshing during sudden aircraft maneuvers (thus ruining uniform development) and how to maintain optimum processing temperatures over widely varying conditions.

Proposed answers varied from applying processing chemicals in a gelatinous form held in place by a transparent thin plastic skin to wrapping the film in a paper saturated with chemicals (see CtE, April 1960, p. 25).

• **In the groove**—Ansco suggested a unique method of applying liquid solutions to develop, clear, and rinse the film. By keeping the actual application of liquid and the supply separated, Ansco solved the sloshing problem. The applicator is a flat rectangular rubber pad with three unconnected oval grooves cut into the side that faces the film. A different solution is pumped into each groove: developer in one, rinse in another, and clearing solution in the third. Because the solutions are sucked from their containers through the grooves back to a tiny pump, the vacuum created pulls the negative tight against the rubber applicator, sealing the liquid in. If a leak develops anywhere in the

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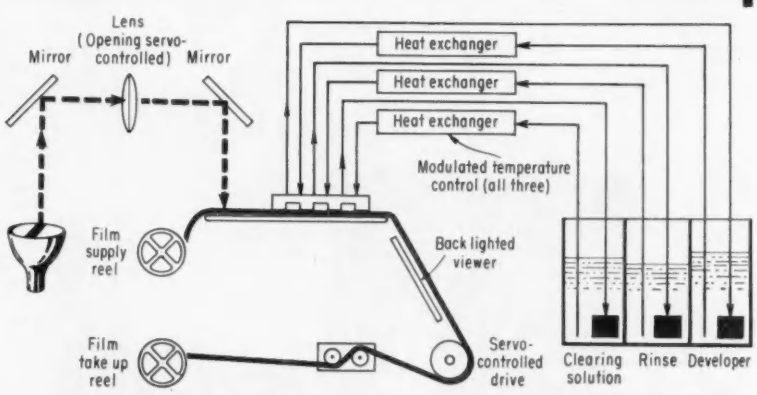


Schematic of military rapid processing system for aerial cameras.

system the liquid will not spray out.

In this form of development, the emulsion has to be very thin, the silver concentration has to be greater, and the gelatine composition less than in conventional film so that the developer can penetrate it quickly. In addition, the emulsion has to be hardened so the film can withstand constant pulling across the rubber applicator even when the emulsion is wet (a normal film's emulsion would scrape right off).

To date, Ansco has delivered 50 rapid processing systems based on this approach to the military sevices, each system different from any other. Since all the cameras were for aerial surveillance, the systems included servo controls to drive the film at a rate determined by the ratio of aircraft velocity to altitude—the higher a survey plane flies, of course, the slower it appears to move relative to the ground. And the military systems have heat exchangers through which the developing solutions pass to maintain the proper temperature for optimum processing. Cost of a complete rapid processing system has ranged from $20,000 to $65,000.

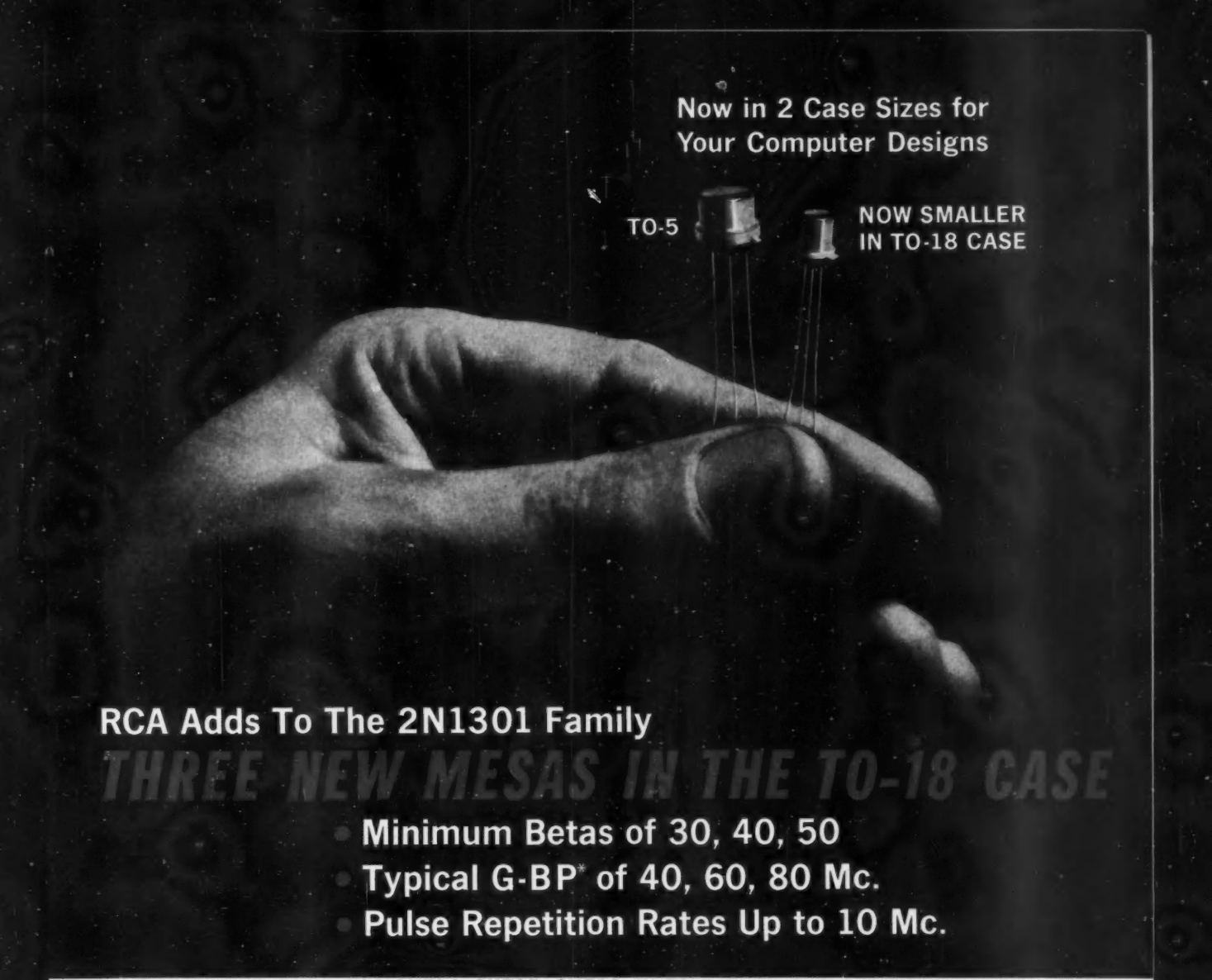
• **Industrial design**—Now the company wants to bring its rapid processing know-how to industry. First job was to design hardware much simpler than that sold to the military since few—if any—industrial applications could afford such expensive gear. The commercial system pictured on page 29 uses the same approach to rapid development but there are no servo controls, the thermistor controlled heat exchanger has been replaced by a simple heater element in the solution containers, one motor replaces six, and the electrical components are not ruggedized or miniaturized. The result: a unit that costs under $10,000.

During the military development, Ansco evolved two stages of processing; both can be used in industrial applications too. One is complete development in which the finished product is a clear negative. The other is arrested development in which all the sensitized silver is not dissolved away. The main difference is timing: arrested development can be viewed within 4½ secs, complete negative processing takes 5 secs. For arrested development, just two solutions are needed—developer and rinse; clear development requires three, the third being a clearing solution.

• **Manometer reading**—Ansco Division sees in testing and data processing a number of possible applications for its rapid processing gear. First industrial installation will be shipped this month to a jet engine plant. Its job: to rapidly process photos of 100 manometer tubes in a test setup so that the photos can be read, measurements taken from the negative and put on punched cards, and the cards run through a computer so the engineers have some idea of the results—while the test is still running. The camera can make almost a continuous record of the movement of the 100 manometer tubes or it can photograph them periodically on a set time schedule.

In a data processing application, the rapid processing techniques can be used to develop the output of a Charactron-type cathode ray tube or other digital display device, thus serving as a high speed hard copy printer. At the IRE show in New York in March, Ansco had a prototype device attached to the Litton fibre optics cathode ray tube to put a descriptive information alongside a photograph.

Now in 2 Case Sizes for
Your Computer Designs



RCA Adds To The 2N1301 Family

THREE NEW MESAS IN THE TO-18 CASE

- Minimum Betas of 30, 40, 50
- Typical G-BP* of 40, 60, 80 Mc.
- Pulse Repetition Rates Up to 10 Mc.

NEW IN TO-18 CASE: RCA 2N794, 2N795, 2N796. IN TO-5 CASE: RCA 2N1300, 2N1301, 2N1683

Once again RCA meets the stringent demands of the dynamic computer industry with new high-speed switching transistors specifically designed for today's military and industrial data processing applications. Here are some of the outstanding features of these high performance types:

- **High Power-Dissipation Capability**–150 mw (max.) at 25°C.
- **High Gain-Bandwidth Product***–40 (2N1300, 2N794), 60 (2N1301, 2N795), 80 (2N1683, 2N796). (Typical Values).
- **High Beta (h_{FE})**–30 min. (2N1300, 2N794), 40 min. (2N1301, 2N795), 50 min. (2N1683, 2N796).
- **Low Total Stored Charge In Saturating Circuits**–400 μμcoulombs (2N1300, 2N794), 325 μμcoulombs (2N1301, 2N795), 160 μμcoulombs (2N1683, 2N796). (Max. Values).
- **Rugged Mesa Structure**
- **Economy Performance**–Top Performance at Low Cost.

Contact your RCA Representative now for complete price and delivery information. For additional technical information, write RCA Semiconductor and Materials Division, Commercial Engineering, Section E-56-NN, Somerville, N. J.

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New Gear Needed to Move the Literature Mountain

Application of computers and data processing equipment to process technical literature is barely keeping pace with the explosion in technical writing.

CLEVELAND—

The abstracting, cataloging, retrieving, and disseminating of scientific and engineering information is becoming big business, and is likely to cost $100 million a year soon. That sums up the main conclusion reached at the annual meeting of the National Federation of Science Abstracting and Indexing Services. Speakers told the group that a widening variety of computers and other data processing equipment were being applied to the technical literature problem.

One speaker, Richard S. Leghorn, president of Itek Corp., hinted that some sort of federal commission is likely to be established soon to study U.S. needs in technical literature processing. One NFSAIS member considered this significant because Leghorn has a close association with Dr. Jerome Wiesner, the Kennedy Administration's special assistant for science affairs. CtE's source guessed that Leghorn was probably expressing Administration views.

• **Mammoth pile of paper**—There seems to be little question that the technical literature problem is exploding its boundaries. At one session, NFSAIS president G. Miles Conrad estimated that at least 1,300,000 technical articles were written and published in 60,000 journals throughout the world last year. And the number of articles is doubling about every eight years. The big question: How can an engineer or researcher find background literature that is helpful for a particular project? One source estimates that possibly half of all R&D money is wasted in duplication.

A new condition tending to complicate the technical literature tangle is that one-third of the articles are now written in Russian, Chinese or Japanese—languages that are totally unreadable by 98 percent of U.S. technical personnel. That means that translation has to be added to the job of retrieving and cataloging literature.

• **Challenge for equipment**—Mechanical translating projects are underway at 11 different companies, said Itek's Leghorn. A typical project is the one IBM is researching for the Air Force. The company has developed a Russian-to-English translator with a 50,000 word vocabulary on photographic discs.

For retrieval, another problem, manufacturers now offer a wide variety of equipment and media. Some typical ones: the punched cards of Jonker's Business Machines Inc.; Minnesota Mining and Manufacturing Co.'s Filmsort microfilm aperture card; Royal McBee's edge-notched card; Magnavox's Magnacard on which a thin piece of magnetic tape is pasted on a plastic card; the Itekcard; Avco's Verac that gains high density storage by microphotography.

• **Where to go for help**—A few large scale literature search systems have already been set up, the meeting heard. The U.S. Patent Office's Operation Haystack has mechanized 3 million complex patent files in 56,000 categories. Search time dropped 50 percent while accuracy increased 100 percent. The Armed Services Technical Information Agency has mechanized the records of 250,000 military R&D projects. And the Central Intelligence Agency has a system that handles 40 million punched cards and now includes microfilm records.

But most companies cannot afford such extensive information abstracting, indexing, and retrieval systems. That is why there was much interest in Dr. E. Castagna's report on a test program to explore the conversion of public libraries into documentation and communication centers. As Director of the Enoch Pratt Free Library in Baltimore, Castagna saw two logical reasons for bringing public libraries into the technical document field: 1) libraries are located throughout the country, close to the technical workers who need the documentary services; and 2) librarians are trained to locate literature sources so they could be turned to the technical literature search with a minimum of extra training and effort.

As the meeting ended, Itek's Leghorn gave the Federation two specific dilemmas that have to be resolved. One lies in indexing and abstracting, that is, methods of supplying the "clues" that can lead to proper materials. The second is a demand to publish information in new forms that can be handled and processed by machines. He offered some radical suggestions such as electro-optical digital and analog recording, memory sheets, talking books, and television records.

VA Steps Up Medical Electronic Study

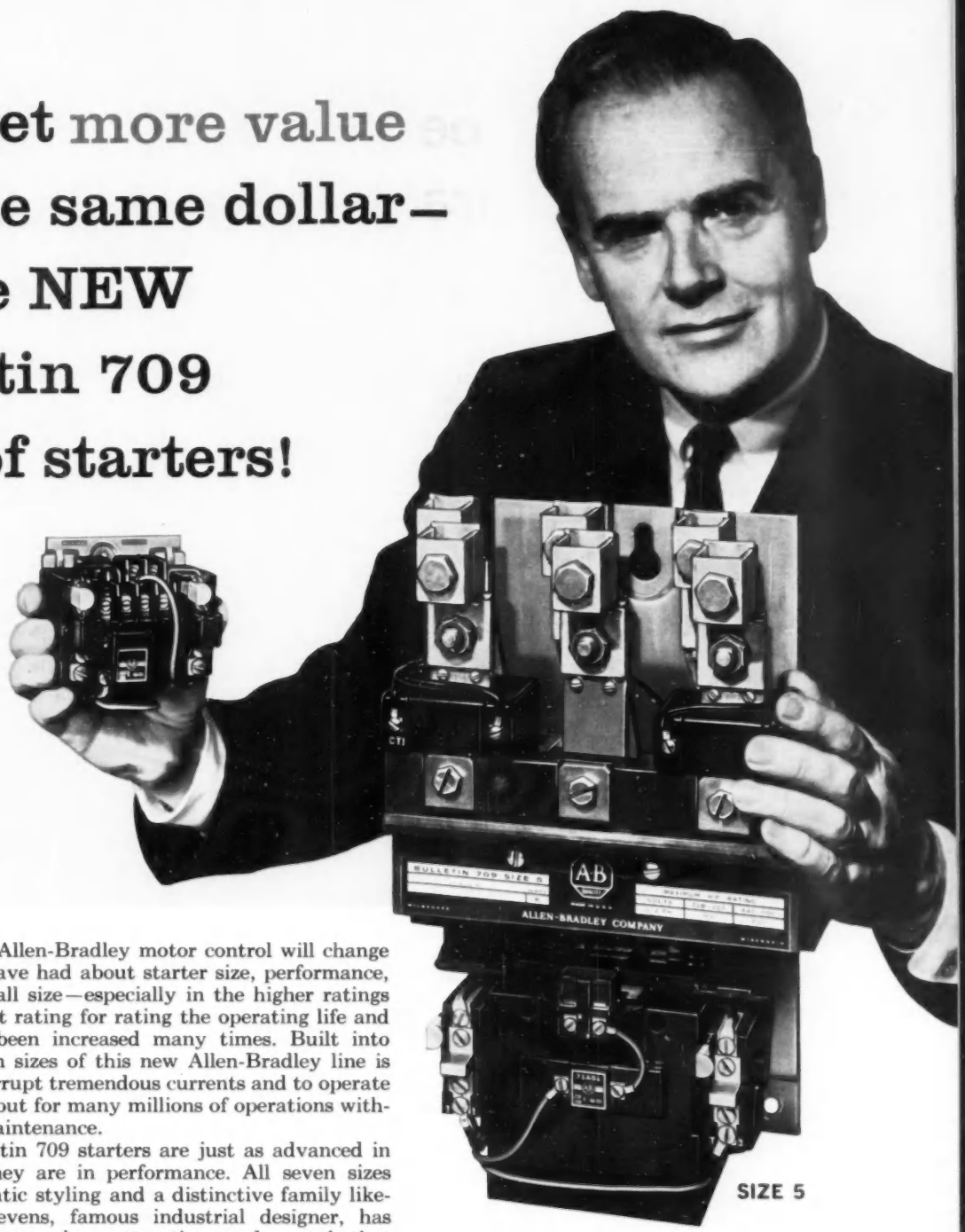
Five different approaches to physiological monitors for surgery are under study. Techniques of space technology move into hospitals.

WASHINGTON—

Electronic measuring and display systems that monitor the condition of patients undergoing surgery are now under development at five hospitals of the U.S. Veterans Administration. What the surgeons want are electronic devices to display instantaneous reports of such physiological variables as heart and brain activity, pulse, respiration, temperature, and blood pressure—before, during, and following surgery.

Space scientists have already succeeded in monitoring these conditions for animals shot into space in rocket nose cones. VA doctors feel the same techniques are applicable in hospitals.

You get more value for the same dollar— in the NEW Bulletin 709 line of starters!



This new line of Allen-Bradley motor control will change every idea you have had about starter size, performance, and life. The small size—especially in the higher ratings—is startling. Yet rating for rating the operating life and reliability have been increased many times. Built into each of the seven sizes of this new Allen-Bradley line is an ability to interrupt tremendous currents and to operate year in and year out for many millions of operations without trouble or maintenance.

The new Bulletin 709 starters are just as advanced in appearance as they are in performance. All seven sizes have an aristocratic styling and a distinctive family likeness. Brooks Stevens, famous industrial designer, has given the enclosures such an attractive, modern style that these new starters will prove a distinct sales asset on any machine or installation.

Why not write today for more information on this revolutionary new line of Allen-Bradley Bulletin 709 *quality* across-the-line motor starters?

Note the compactness of both the smallest and largest starter in the new Bulletin 709 line. Ratings up to 100 hp, 220 v; 200 hp, 440-550 v.

10-61-RM

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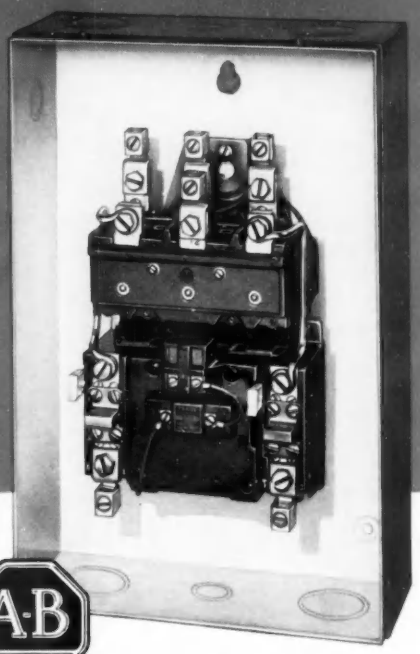
Allen-Bradley Co., 1316 S. Second St., Milwaukee 4, Wis.

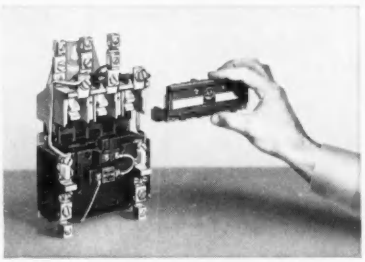
QUALITY MOTOR CONTROL

Features of the NEW Allen-Bradley starter line that are of value to you!

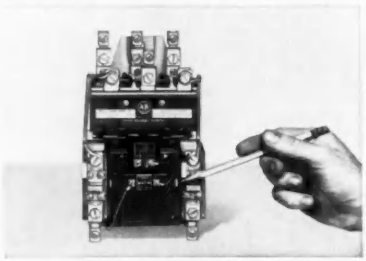


New Bulletin 709 Size 3 across-the-line motor starter. Note the generous space for wiring, accessible terminals, and white interior.

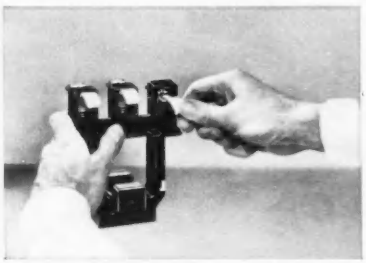
Every detail of the new Allen-Bradley motor starters has been designed to help make this the best line of motor control on the market. Remarkably small in size, each starter is a giant in performance. Being light in weight, these starters are easy to handle and a cinch to install. The generous wiring space, full front wiring, white interiors, and convenient knockouts make installation easy. The enclosure cover is firmly held with a quarter-turn fastener. All installation, inspection, and maintenance operations can be handled from the front—as shown in the illustrations below—without the use of special tools.



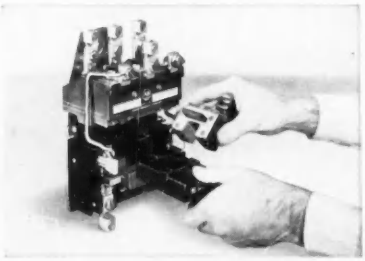
QUICK, EASY CONTACT INSPECTION—When the arc hood front cover is removed by loosening two captive screws, contacts are plainly visible from the front.



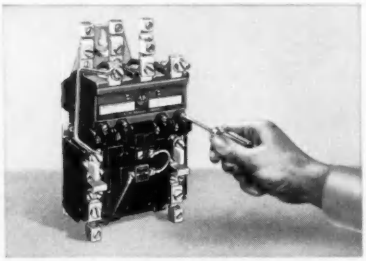
CONTACT POSITION INDICATED—Two slots in the coil cover show the position of the movable contact support—tell whether contacts are "closed" or "open."



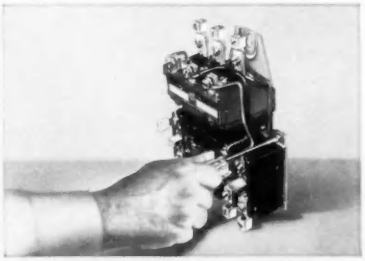
CONTACTS EASILY REPLACED—Depress the spring slightly, and the movable contacts can be lifted out of the molded support and the new contacts slipped in.



COIL EASILY CHANGED—When the coil cover is removed, coil and magnet yoke can be lifted out from the front. They are impossible to replace incorrectly.



AUXILIARY CONTACTS EASILY ADDED to the front of the starter. Two extra auxiliaries can be added to Sizes 0, 1, and 2 starters, and four, to Sizes 3, 4, and 5.



A THIRD OVERLOAD RELAY CAN BE EASILY ADDED in the field, from the front of the starter. And the only tool needed is a common screwdriver.

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QUALITY MOTOR CONTROL

WHAT'S NEW

Their long range goal: to make complex surgical procedures such as neurosurgery and open heart operations safer for patients.

• **Advanced system**—The most advanced of the new systems is already operating at the VA's Pittsburgh (Penna.) hospital, equipment developed under a private contract by the Epsco Medical Div. of Epsco, Inc. The master monitoring system has eight channels: two are electroencephalographic (brain wave), two electrocardiographic (heart action), two vascular pressure (blood pressure), one temperature, and one respiration.

In Pittsburgh, the monitoring display oscilloscope has been placed in a stanchion in the operating room ceiling so that every member of the surgical team can see it during an operation. A permanent record from all channels unfolds in front of the anesthesiologist and the surgeon. Only one cable leads from the patient to the equipment. The Epsco design has been transistorized and miniaturized so it is portable. If needed, the electronic monitor can be moved anywhere in the hospital with the patient.

VA personnel are also working with engineers at the Massachusetts Institute of Technology to develop a system primarily for treatment of patients with Parkinson's disease and other central nervous system disorders.

• **Syracuse, muscle action**—In the VA hospital in Syracuse, doctors are concentrating on a system that will monitor vascular flow and muscle action. Much of the work so far has been to develop instrumentation that will show rate of change rather than readings at a given instant.

At Coral Gables, Florida, development work is aimed at a research area. The system is to monitor life processes near hibernation. At these levels, circulatory demands and the oxygen and carbon dioxide exchanges are minimum for survival, so that measurement of any change is vital.

One of the most flexible projects has been proposed by the Chicago VA hospital. The research: to develop a monitoring system that can be used for any complex operation.

So far the VA has not spent any giant sums for their monitoring research. The system in Pittsburgh cost about $18,000 and the one at Syracuse is estimated at about $20,000. Other VA hospitals are now preparing projects to complement those in work. "Any that have merit," says Dr. Lyndon E. Lee, Jr., Head of Research in Surgery for the VA, "will likely be approved".

WHERE ARE YOU IF IT DOESN'T LIGHT IN SALT AIR?

Pressure switches that only turn on warning lights in uncontaminated air find it tough going in such a simple thing as salt air atmospheres.

The way you beat this problem is to check the pressure switch under every known operating requirement . . . not just in a vacuum, or 0% humidity or just at sea level, for instance.

Take Model 6621 shown at right that can do so many jobs . . . operate warning lights, measure fuel and oil pressures, actuate air-conditioning for electronic gear. This model, in ranges from 5 to 1000 psig, operates between −65 to 275°F, withstands shock up to 100 g's and vibration to 2000 cps. It is only 1 1/16" diameter by 2 1/2" and weighs but two ounces.

Copy us. Test it yourself for six weeks under all the requirements of your job.

Or save six weeks by checking our own test data on a full line of pressure switches for the type that meets your needs best. Call Mr. Charles Colt at Consolidated Controls, Bethel, Conn. Phone Pioneer 3-6721, DDD Code 203.

Inches of Water to Hundreds of Atmospheres

Model 6621 shown above is one of more than 300 pressure switches available from Consolidated Controls for missile, aircraft and nuclear applications. Working pressures range from 10" of water to 10,000 psi at ambient temperatures from −65°F to 1000°F. Standard models for

- high vibration
- differential pressures
- hydraulic
- miniaturized applications
- high temperature

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TO A
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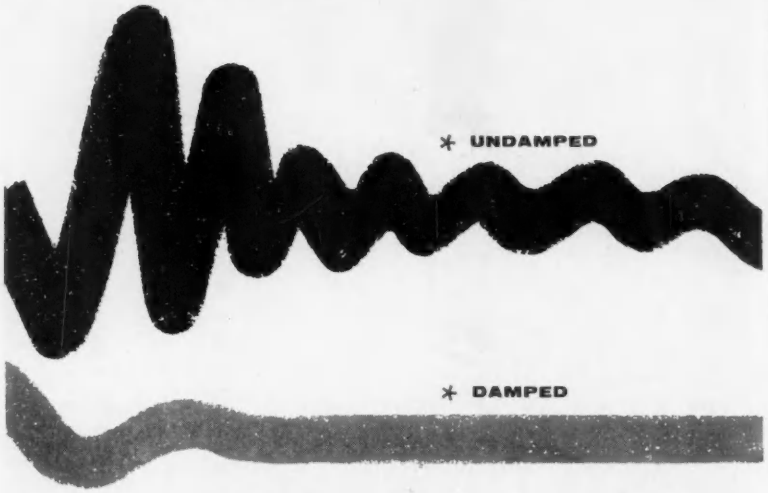
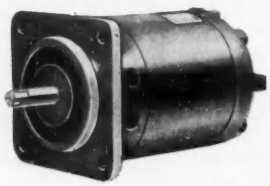
PROBLEM



DAMPED HYSTERESIS SYNCHRONOUS MOTOR — MODEL FBC3830H-41

It is characteristic of hysteresis synchronous motors that any variation in the applied voltage, frequency, or load will cause an initial hunting or oscillation of the output shaft. However, this condition can be controlled **imc** hysteresis synchronous motor, model FBC3830H-41 is designed to minimize hunting or oscillating characteristics.

The built-in damping capabilities of this 3 speed motor results in fast return to the original steady state condition. Single speed as well as multiple speed damped units are available.



SPECIFICATIONS

FREQUENCY:	60 cps
VOLTAGE:	115 volts, single phase
SPEED:	3600/1800/900 rpm
RATED HORSEPOWER:	1/20 - 1/40 - 1/100
INPUT POWER:	2.2/1.4/0.9 amps
RATED TORQUE (in-oz):	14/14/11

APPLICATIONS — Ideally suited to data and video recorder applications, machine tool controls, computer applications, or any application where low noise, low initial hunting of output shaft, and quick speed recovery is required. **May imc assist in solving your hysteresis synchronous motor hunting problems?**

Write for additional information, or send for hysteresis synchronous and torque motor catalog.

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EASTERN DIVISION
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OTHER PRODUCTS: propeller and vane-axial fans/centrifugal blowers/heat exchangers/dynamotors and inverters/servo motors and motor tachometers/torque motors/induction motors/dc motors

**Shown above are illustrations of initial hunting or oscillation and constant speed recovery patterns of damped (damping ratio of 0.7 to 0.9), and undamped hysteresis synchronous motors.*

36 CIRCLE 36 ON READER SERVICE CARD

WHAT'S NEW

Lawyers Eye Computer Legal Tangles

Influx of data processing originates some unexpected problems that intrigue the legal profession.

WASHINGTON—

Lawyers, trying to catch up with the computer age, met in Washington last month to discuss some new legal problems arising from the spreading application of data processing machines in industry.

They asked themselves such hypothetical questions as these:

▶ If an electronically-processed check is "bounced" erroneously, whose fault is it?

▶ If a corporation's management lags behind competitors in installing data processing systems, is the company laying itself open to charges of mismanagement?

▶ Is information on magnetic tape, punch cards or other computer apparatus admissible as evidence in a court of law?

▶ If a non-mechanized railroad has a train wreck, can the road be sued on the premise that the accident would not have occurred with modern traffic controls?

Listeners attending the three-day forum, sponsored by the Joint Committee on Continuing Legal Education of the American Law Institute and the American Bar Association, made no effort to give firm answers to these questions. Rather, the meeting marked the first time many of them had even considered such problems.

Roy N. Freed, chairman of the meeting and an associate of the Philadelphia law firm of Bullard, Spahr, Andrews & Ingersoll, explained that such legal problems are just starting to reach the courts. The idea behind the forum, he said, is to get lawyers thinking now about how to solve them before they become hopelessly tangled.

In addition to hearing their colleagues discuss the technical legal aspects of computers, the lawyers also got a primer course in electronic data processing. Arnold I. Dumey, president of Data Sciences, Inc., Great Neck, N. Y., gave the lawyers some suggestions about how computer specialists can assist them. Simple discussion of what computers are all about can be helpful, Dumey said, "so that the lawyer knows which terms mean essentially the same thing, and what differences exist among them."

Teletype Model 28 ASR—
page printer, tape reader, tape punch . . .
all in one!

A compact data communications center

The Teletype Model 28 ASR set is a machine of many talents—time and money saving talents that are ready to go to work in your data and message communications systems.

The page printer provides facilities for sending and receiving on message paper or sprocket-fed forms. It can also be used for preparing records or as a read-out device. Platens are available to accommodate a variety of form widths, from 3⅝″ to 9″.

The punched tape equipment is unusually flexible and versatile. Facilities are provided for encoding data into tape (with or without printing on the tape) . . . transmitting from tape . . . integrating repetitive data from previously prepared tape with variable data by keyboard . . . obtaining punched tape as a by-product of communications for computer and other business machine input. There is a choice of four different punches and four different readers and, where additional tape punch facilities are needed, a model is also available with an auxiliary tape punch.

In addition, the Model 28 ASR comes equipped with a "big plus"—the Stunt Box, a built-in programming mechanism that offers an inexpensive solution to a wide variety of remote control and switching tasks, such as automatic station selection and telemetering.

All of these facilities are available to you in a compact console measuring approximately 39″ high, 36″ wide and 23″ deep.

Teletype Corporation manufactures this equipment for the Bell System and others who require the utmost reliability from their data communications facilities. Teletype equipment can be used with Data-Phone and other communications services.

For a free brochure on the Model 28 ASR, write to Teletype Corporation, Dept. 21-D, 5555 Touhy Avenue, Skokie, Illinois.

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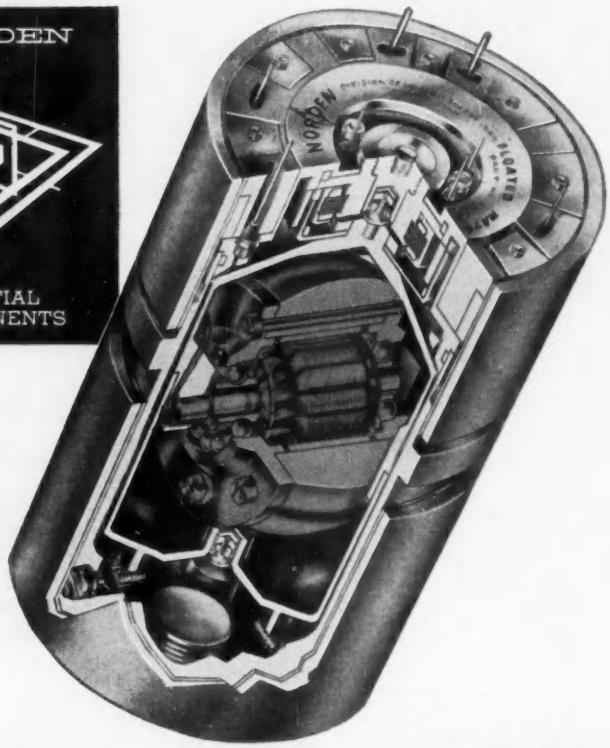
CIRCLE 37 ON READER SERVICE CARD

NORDEN

INERTIAL COMPONENTS

NORDEN MINIATURE FLOATED RATE INTEGRATING GYRO



Combines High Accuracy and Increased Reliability

Norden's fully floated integrating gyro, with a single degree of freedom, delivers maximum performance in a minimum package. Used for precision measurement in inertial systems . . . for airborne and marine fire control systems . . . and as the heart of Norden's new low threshold rate system . . . this new design offers:

- **LOW DRIFT RATES** through high float volume and concentration of floated weight in flywheel.
- **HIGH RESISTANCE** to shock, vibration and sustained acceleration through rugged design.
- **INCREASED STABILITY** by a simplified design utilizing micro precision spin bearings and fewer floated parts.
- **HIGH RELIABILITY** because of low (12,000 rpm) speed; all materials matched for temperature expansion coefficient; preloaded motor assembly run in for 150 hours and centrifuged at 20 g's to assure stability.
- **PROVED PERFORMANCE**—flight tested for 15 months in Norden's "20-pound pilot" inertial platform.

FOR GIMBALLED OR STRAP-DOWN SYSTEMS—Models are available for stabilizing gimballed platforms (RI-203 series) as well as for strap-down applications (RI-210 series).

TYPICAL SPECIFICATIONS

Weight	0.84 lbs.
Size	2 x 3.1 inches
Angular Momentum	330,000 gm-cm²/sec
Synchronizing Speed	12,000 rpm
Operational Life	3,000 hrs.
Gyro Performance	
Drift, Vertical (output axis vertical)	0.01°/hr (short term, 1 sigma)
Drift, Azimuth (output axis horizontal)	0.02°/hr (short term, 1 sigma)
Drift, Azimuth, day to day, untrimmed	0.1°/hr (1 sigma)

For illustrated literature including specifications and performance data, call TEmple 8-4471 or write to:

NORDEN

division of UNITED AIRCRAFT CORPORATION

NORWALK, CONNECTICUT

French Spectacular

France vies for a larger share of the bustling European control market with a giant show. Over 400 exhibitors will display products from tiny new components to industrial computer control systems.

PARIS—

Mesucora, France's first instrument and control show, is being launched in the grand manner: more than 400 exhibitors will occupy over 375,000 square feet in the spectacular umbrella-roofed Centre National des Industries et des Techniques Exhibition Hall. Across Paris in the Salle d'Iena, a six-day technical conclave will hear 42 papers in a state-of-the-technology report on new measurement and control devices. From May 9 to May 17, control engineers will make Mesucora their headquarters.

The show is convincing evidence that France too has set its economic sights on the European instrument and control market, which many marketers feel is the most exciting in the world today. For proof they point to the more than 100,000 interested visitors who attended Interkama in Dusseldorf last November, or the 42,000 at the Milan Machine Tool Show.

Certainly the steel, chemical and metalworking industries of Europe are in foment. The success of Europe's two economic communities has stimulated large scale expansion and modernization. Increased production has become European industry's motto. And continental control makers are making the most of it.

The six categories of display at Mesucora emphasize the role measurement and control can play in this drive for more production. They are:

control and regulation equipment
automation
meter and measuring instruments
relays
optical instruments
radio and electronic equipment

• **International scope**—Although Mesucora is the child of 14 French associations—who are using the show to publicize the French control industry—the local exhibitors are in for some stiff world-wide competition. More than half the exhibits will house displays from foreign countries: 110 companies from Western Germany alone; 70 from the United States; 55 from Great Britain; and 40 from Switzerland. Italy, Belgium, Holland, and Denmark will each send 14 firms.

French exhibitors are expecting more than sales at Mesucora. They see in it an opportunity to lay out the entire French control industry for everybody to peruse, particularly the management of small user companies who need to learn what French control firms can offer. Their severest obstacle, makers feel, is ignorance of what is available rather than a lack of desire to buy.

German companies, on the other hand, are interested in increasing their share of sales in France. British exhibitors are coming to Mesucora more from curiosity than conviction; most are waiting to see what kind of attendance shows up, but are afraid to stay away in case the show is as successful as the French expect.

• **A quick look at France**—A survey of French interest in control indicates five main areas of activity will highlight Mesucora.

▶ Data logging—most active interest currently in France.

▶ Process control—new electronic systems continue to appear, but active development of pneumatic controls is underway too.

▶ Process control computers—high application rate.

▶ General instrumentation – some novel innovations.

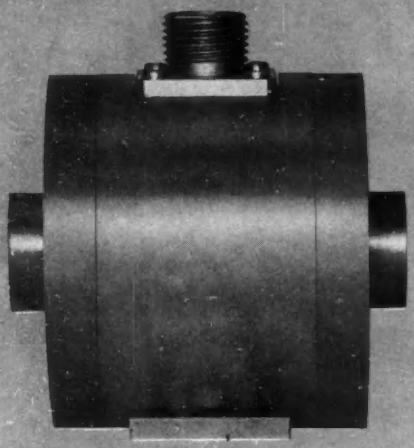
▶ Static switching—installation rate has doubled each year since 1957.

One surprising deficiency is the lack of machine tool control innovations.

France's interests, like many other countries, have been shaped by heavier than usual government expenditures in research. Since 1957 government scientific spending has been up sharply. In addition, a Delegation General a la Recherche Scientifique et Technique was commissioned by President Charles de Gaulle to reorganize France's scientific institutions. From this reorganization has come improved stature for French scientists.

The current research program runs about $200 million, the bulk of it going to government research laboratories, nationalized industries such as Electricite de France (EDF), and university and defense laboratories. France has been putting large sums into a nuclear program and somewhat smaller sums into rocket studies.

Government installations are breaking the path for private industry in several difficult projects. EDF, for example, has invested heavily in data logging and computer control equipment at its Chinon nuclear power plant (Digital Computers Monitor Nuclear Steam Generator, CtE, pp.



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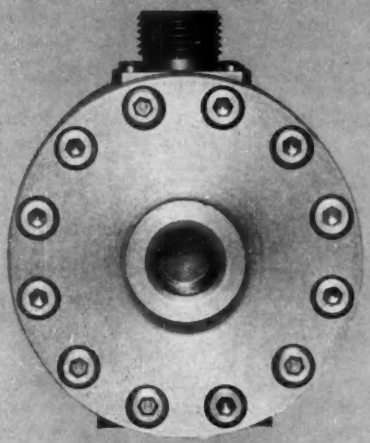
CEC's NEW HIGH-LINE, LOW-DIFFERENTIAL TRANSDUCER



There's a port on each end of CEC's Type 4-351 Unbonded Strain Gage Pressure Transducer—and both are suitable for corrosive liquid or gas media. This new instrument is an ideal high-line, low-differential transducer for use in orifice-plate flow meter applications.

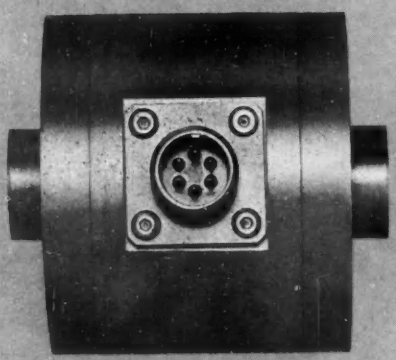
The 4-351 is the smallest unit of its type on the market and offers the highest performance of any comparable instrument. Look at some of its specs:

Differential pressure range — ±15 psid through ±100 psid. 10 X overpressure.

Line pressure rating — 5,000 psi.

Sensitivity — ±50 mv.

For complete information, call your nearest CEC sales and service office or write for Bulletin CEC 4351-X1.



Transducer Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

A SUBSIDIARY OF Bell & Howell · FINER PRODUCTS THROUGH IMAGINATION

WHAT'S NEW

. . . the optimistic view toward digital equipment for data logging and control means several new systems . . .

127-131, March 1961). At least ten computers will be involved when all three reactors are completed. Computer makers hope that the lessons learned at Chinon will convince private companies to make similar investments in logging and computing equipment.

• **Show highlights**—Because of the optimistic view toward digital equipment for data logging and process control, a number of new machines will be introduced at Mesucora, although some are just new to France.

▶ Item. Compagnie Generale de Telegraphie Sans Fils (C.S.F.) has a new data logging system, completely transistorized, operating on 100 channels with a 65 second scanning period. Over-all accuracy is said to be four parts, in ten thousand for the three sensitivity ranges between 40 millivolts and 150 volts. C.S.F. also is close to announcing a 500 channel model with an over-all accuracy of 0.2 percent.

▶ Item. Societe d'Electronique et d'Automatisme will show an unusual electronic and mechanical scanning system. It has a free-running Nomotron counter to pulse thyratrons that operate mechanical scanning relays. Relay reliability, which is normally a prime maintenance worry, is better than that of the thyratrons and counter elements, said a SEA spokesman.

▶ Item. Controle Bailey will show a French-made model of the American Bailey type 750 data logging system.

▶ Item. Compagnie de Compteurs will display the American designed Packard Bell PB 250 process control computer, a relatively low priced machine which CDC will manufacture in France.

Two other computer exhibitors who will be active at Mesucora are Cie Europeenne d'Automatisme Electronique (which manufactures the American RW-300) and Centre d'Automatisme de La Compagnie Generale d'Electricite which has installed off-line CITAC computers at the Chinon nuclear installation.

• **Process control innovations**—At least two new electronic control systems will be introduced at the show, both fully transistorized. One, developed by Cegea, uses a one to five volt dc input and a one to five milliamp output. The other, to be introduced by Meci, operates on a zero to four milliamp or one to five milliamp

← CIRCLE 40 ON READER SERVICE CARD

input and output.

Meci will also introduce a new humidity measurement controller, which has been used to regulate air moisture in a blast furnace. Another new Meci product is an instrument that performs square root calculations on pneumatic signals. Designed primarily for Bernoulli Law corrections on flow measurements, the device is available in two forms; both use simple mechanical linkage computers.

Controle et Regulations will exhibit a unique pneumatic five-tube umbilical cord system on miniature pneumatic recorders. With this cord an instrument can be pulled out of a panel without pneumatic disconnection. These new recorders also have four servomotor operated pens and a built-in setpoint control.

• **Programming idea**—Another innovation for the steel industry is magnetic tape programming of automatic charging for a blast furnace, developed by CDC. The weight of ingredients is coded onto the tape which forms an analog of the actual conveyor belt. As the tape passes under a reading head, the readout initiates the proper hopper discharge of the amount coded until the total weight checks with the weight set in by the operator.

• **New instruments**—A few of the innovations at Mesucora solve somewhat off-beat problems. For example, Ets Jules Richards has built an icy-road warning detector. Detecting an icy road condition by a combination of temperature and humidity measurements, it has a mercury-in-glass contact thermometer and a hydrometer.

CSF is marketing a statistical voltmeter, based on an original invention of Electricite de France. Designed to measure line voltage fluctuations statistically, the voltmeter has a stepping switch calculator that measures mean, mean square, and r.m.s. errors—to an accuracy better than 0.5 percent.

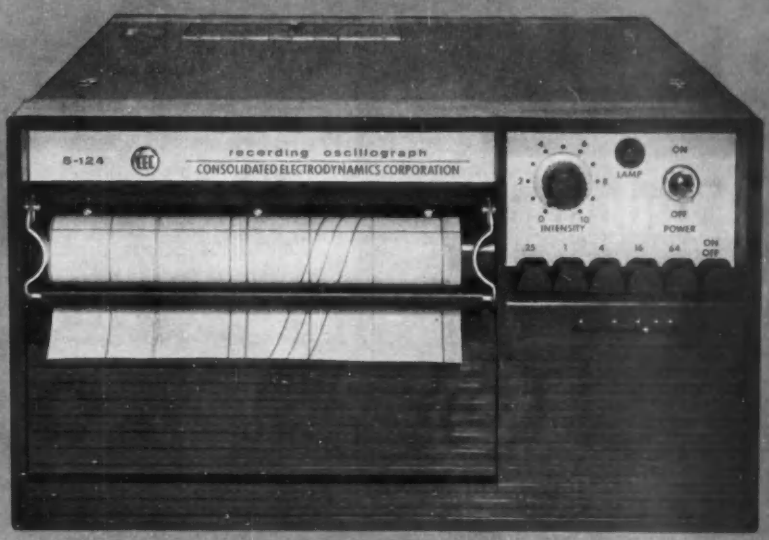
—Derek Barlow

New Soviet Science Group

Concern over the long delay in introducing scientific developments into industry has forced a change in Russian organization. Last month, the Soviet government quietly abolished the State Scientific and Technical Committee.

In its place, the Russians have formed a State Committee on Coordination of Scientific Research, under M. V. Khrumichev. Now the Soviet Academy of Sciences will concentrate its activity on "comprehensive development of fundamental sciences providing close relation with practical tasks of people's economy".

CIRCLE 41 ON READER SERVICE CARD→



Inside this portable recording oscillograph...

A FOCUSED PRECISION OPTICAL SYSTEM TO ASSURE HIGHEST TRACE RESOLUTION

The high-efficiency optical system of CEC's 5-124 Recording Oscillograph concentrates more high actinic light on the record... permits a writing speed of 50,000 ips with trace widths of 0.010″ or less.

Optics are specially treated for higher light transmissibility. This means "big" oscillograph capability in a portable, low-cost instrument. The 5-124 easily records and resolves phenomena occurring in intervals as short as 500 microseconds... boasts 18-channel capacity... delivers ready-to-read print-out records that eliminate processing problems.

Among the 5-124's standard features are pushbutton control, intensity control, unexposed footage indicator, individual input connectors and automatically regulated galvanometer lamp circuit. These optional features are available: grid lines (1/10″ or mm), trace identification and numbering, full-width timing lines and galvanometer block heaters.

For complete information, call your nearest CEC sales and service office or write for Bulletin CEC 5124-X14.

Data Recorders Division CEC

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

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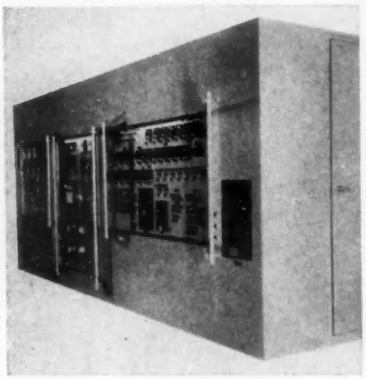
. . . The Company We Keep have many names, one standard: all are perfectionists. For Custom Control Centers, they frequently call on us . . . we're perfectionists too! Won't you join "The Company We Keep?" Contact us for all your Control Centers.



The Electro-Mech panel shown above controls a large water conditioning system. It has over 3000 relay contacts and 13,000 feet of wire. Electro-Mech excellence of design and meticulous craftsmanship, which makes possible the flawless operation of systems such as this, are hallmarks of perfectionists.

Allow us to submit a proposal on your control system needs.

Electro-Mech Corp., Norwood, N. J.

Electro-Mech

Electronics Pegs Hopes on Industrial Sales

Electronics goods suppliers are taking a harder look at industry. Some companies have developed sharp approaches for getting industrial equipment in the field, but overall sales are slow because of reliability worries and too soft a sell.

After talking about selling to the industrial market for five years, electronics manufacturers are finally doing something about it. The discovery that the explosive rate of growth of the industry is slowing down as their key markets in the military, entertainment, and communications fields reach plateaus has pushed them into action. Companies normally used to sharply rising sales curves have started receiving painful setbacks.

▶ **Item.** Last month, although the Kennedy administration asked Congress for an additional $2 billion for military spending — some of which would end up in the coffers of electronics companies—the Defense Dept. cut back the controversial B-70 Mach 3 bomber program to developmental status again and dropped the aircraft nuclear propulsion program completely, thus suddenly ending sizable electronics contracts in the hands of a number of suppliers.

▶ **Item.** Hoffman Electronics Corp., longtime builder of entertainment products, has been forced out of the TV and stereo business because it could not "build . . . quality . . . products to sell at prices now prevailing and still obtain a proper profit".

Since 1950 the electronics industry has enjoyed fantastic growth. It has exploded from a group of about 1,000 companies with annual sales of about $2.5 billion to the 3,500 companies who sold almost $11.5 billion worth of goods last year. The industry started in communications and was raised to a healthy child by consumers' rapid acceptance of television. But it has been the military electronics business that has nurtured the electronics colossus. Last year military electronics accounted for roughly half of total sales.

Military business has been an ideal way to get a little company rolling. Government research and development contracts pay for setting up a tiny laboratory and the salaries of a few engineers. A small amount of assured profit is often enough to finance the development of bread-and-butter components that can be sold to other military suppliers. Or the little company might start by building the custom odd-ball gear required for special projects. This arrangement has worked to everybody's advantage: the little companies were able to breathe and the government received the kind of research and products that bigger, already established companies didn't want to touch.

• **Chancy business**—But the military business has always had some undesirable sidelights. Profit margins, particularly on systems engineering or R&D contracts, are notoriously small —in some contracts as little as 1 or 2 percent. And military business has always had a threat of uncertainty. A change in tactical plans, an outburst in Congress, or an election can end a big piece of business.

Industrial markets look more stable. And such innovations as computer control, data logging, numerically controlled machine tools, and electronic process control open up what appear to be broad, lush selling areas.

The big questions now for electronic suppliers are how to get into these fields and how to sell them.

One way is to take equipment designed for a military application, that has an industrial counterpart, and redesign it. That's what Diehl Manufacturing Co. has done. It sells a broad line of MIL-spec synchro components. Its industrial synchros are identical electrically but are less expensive because they do not have ruggedized cases or special connections. Navigation Computer Corp. has also followed this tack. Navcor supplies digital modules for military use; it has redesigned them for industrial voltages.

Another approach is to take know-

67 . . . good reasons why you can standardize with

*WIDE RANGE MODELS

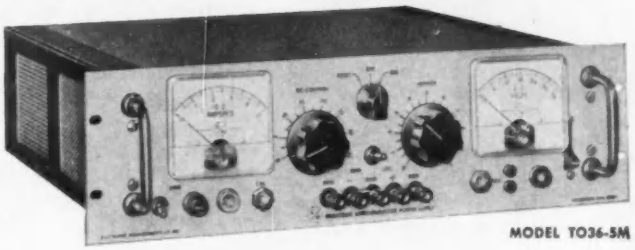
D-C OUTPUT VOLTS	D-C OUTPUT AMPS	MODEL NUMBER	DIMENSIONS IN INCHES H	W	D
0-7	0-30	*TO7-30	15¾	19	16
0-7	0-15	*TO7-15	8¾	19	15
0-7	0-10	*TO7-10	7	19	15
0-7	0-5	*TO7-5	5¼	19	15
0-7	0-3	*TO7-3	3½	19	12½
0-14	0-20	*TO14-20	15¾	19	16
0-14	0-10	*TO14-10	8¾	19	15
0-14	0-7.5	*TO14-7.5	7	19	15
0-14	0-5	*TO14-5	5¼	19	15
0-14	0-3	*TO14-3	3½	19	12½
0-32	0-30	TO32-30	15¾	19	16
0-32	0-15	TO32-15	8¾	19	15
0-32	0-10	TO32-10	7	19	15
0-32	0-5	TO32-5	5¼	19	15
0-32	0-3	TO32-3	3½	19	12½
0-36	0-30	TO36-30	15¾	19	16
0-36	0-15	TO36-15	8¾	19	15
0-36	0-10	TO36-10	7	19	15
0-36	0-5	TO36-5	5¼	19	15
0-36	0-3	TO36-3	3½	19	12½
0-60	0-15	TO60-15	15¾	19	15
0-60	0-7.5	TO60-7.5	8¾	19	15
0-60	0-5	TO60-5	7	19	15
0-60	0-2.5	TO60-2.5	5¼	19	15
0-60	0-1.5	TO60-1.5	3½	19	12½

*MODELS MARKED WITH AN ASTERISK ARE PROGRAMMABLE.

†NARROW RANGE MODELS

5-7.5	0-30	T6-30	15¾	19	16
5-7.5	0-15	T6-15	8¾	19	15
5-7.5	0-10	T6-10	7	19	15
5-7.5	0-5	T6-5	5¼	19	15
5-7.5	0-3	T6-3	3½	19	12½
7-11	0-15	T9-15	8¾	19	15
7-11	0-10	T9-10	7	19	15
7-11	0-5	T9-5	5¼	19	15
11-14	0-30	T12-30	15¾	19	16
11-14	0-15	T12-15	8¾	19	15
11-14	0-10	T12-10	7	19	15
11-14	0-5	T12-5	5¼	19	15
11-14	0-3	T12-3	3½	19	12½
14-17	0-15	T16-15	8¾	19	15
14-17	0-10	T16-10	7	19	15
14-17	0-5	T16-5	5¼	19	15
17-20	0-15	T19-15	8¾	19	15
17-20	0-10	T19-10	7	19	15
17-20	0-5	T19-5	5¼	19	15
20-23	0-15	T22-15	8¾	19	15
20-23	0-10	T22-10	7	19	15
20-23	0-5	T22-5	5¼	19	15
22.5-27	0-30	T25-30	15¾	19	16
22.5-27	0-12	T25-12	8¾	19	15
22.5-27	0-10	T25-10	7	19	15
22.5-27	0-5	T25-5	5¼	19	15
22.5-27	0-3	T25-3	3½	19	12½
25-31	0-30	T28-30	15¾	19	16
25-31	0-12	T28-12	8¾	19	15
25-31	0-10	T28-10	7	19	15
25-31	0-4.5	T28-4.5	5¼	19	15
25-31	0-3	T28-3	3½	19	12½
31-33.5	0-30	T32-30	15¾	19	16
31-33.5	0-12	T32-12	8¾	19	15
31-33.5	0-10	T32-10	7	19	15
31-33.5	0-5	T32-5	5¼	19	15
31-33.5	0-3	T32-3	3½	19	12½
33.5-36	0-30	T35-30	15¾	19	16
33.5-36	0-12	T35-12	8¾	19	15
33.5-36	0-10	T35-10	7	19	15
33.5-36	0-5	T35-5	5¼	19	15
33.5-36	0-3	T35-3	3½	19	12½

†ALL NARROW RANGE MODELS ARE PROGRAMMABLE.



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*REGULATION: 0.03% or 0.01 V from no load to full load and 105 to 125 V line. (0.1% or 0.01 V for 3-amp models.)

RIPPLE: Less than 1 millivolt rms.

INPUT: 105 V to 125 V, 50 to 60 cps.

CIRCUIT PROTECTION: Four-year field-tested electronic and electrical circuit protection.

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Unique construction permits the entire probe and leads to withstand temperatures of the hot junction, which may be (1) exposed, (2) sealed and insulated, or (3) grounded and flattened. All configurations are designed for minimum disturbance of environment.

⅓ the size of a human hair...the sensing element wires are insulated with pure fused ceramic that does not pick up moisture from the air and has a voltage breakdown of 10,000 volts at room temperature. The probe is .014 in. dia., and the lead wires are .010 in. dia. for easy handling.

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WHAT'S NEW

how polished in military applications and apply it to solve industrial problems. Packard-Bell has tried this. After developing a number of special purpose computers for the military services, the company put its knowledge of digital techniques to work to produce the PB 250, a computer for process control.

Still another approach is to take the military experience of one part of a company and blend it with the industrial savvy of another. Cutler-Hammer, veteran electrical control maker, has combined the sophisticated electronic techniques developed in military projects by its subsidiary Airborne Instrument Laboratory and the marketing skills of its industrial salesmen to invade the fields of electronic controls for printing, special purpose steel mill data accumulators, and custom-built machine tool like the electronically controlled grinder that makes Gillette's super sharp blades.

Developing the product line is only half the battle. Selling industrial buyers, who have every bit as much inertia about electronic equipment as some government buyers show to new ideas, is the other half.

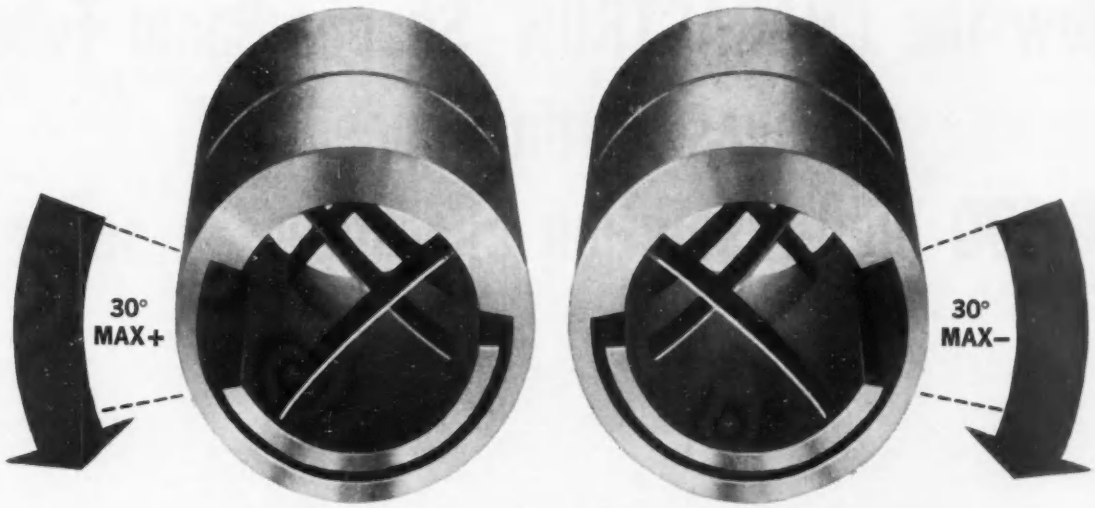
Unfamiliarity often breeds distrust, in the opinion of F. J. Bigda of Transitron Electronic Corp. Industrial buyers still fear the unreliability of electronic devices, but military successes, he notes, have begun to influence some holdouts. Also, Bigda says, industry needs help in applying electronics; Transitron goes out of its way to provide circuit design aid.

• **Well placed doubts**—Dr. Bernard Oliver, director of research and development for Hewlett-Packard Co., feels sympathy for skeptical industrial buyers. While the military can afford to pay for the often fantastic reliability figures it specifies and there is usually no other way to solve a missile control problem, industry must have reliability to protect its equipment investment—and at industrial prices. And since it has gotten along without electronics before, it often doesn't want to pay premium prices for guaranteed reliability. Dr. Oliver feels industrial buyers must insist on reliability and that electronics makers must supply it at a price industry is willing to pay.

A spokesman for another large test equipment maker, Ivar G. Easton of General Radio Co., also looks to military reliability successes to eventually swing industry to electronics.

• **Built-in reliability**—The biggest single trend in the electronics field

(Continued on page 182)



NEW FROM BENDIX!
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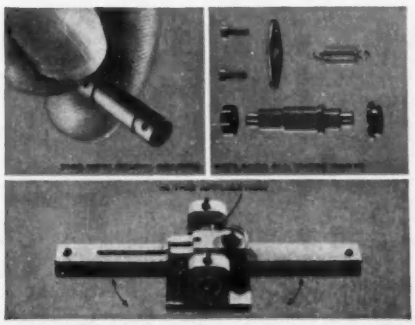
Positively no friction or backlash... requires no lubrication

It's the Bendix Flexural Pivot. Made of pairs of flat, crossed springs, the new Bendix® Free-Flex Pivot Bearing is completely free of friction and backlash—and eliminates the need for lubrication. This compact, integrated unit is easy to install, easy to use. And its performance is consistency itself.

Bendix Free-Flex Bearings come in two types. The Cantilever type for supporting overhung loads. The double-end-supported type for bridge-supporting a central load. Both are corrosion-resistant steel. Both have high lateral and radial rigidity plus low torsional rigidity.



Before Free-Flex, this air data sensor component had six parts, requiring machining tolerances of .0003". With Free-Flex Bearing, the closest tolerance required is only .005".

Our first low-cost standard models come in 3/16", 1/4", 3/8", and 1/2" diameters with three deflection limits: ±30°, ±15°, and ±7.5°. Fast delivery of any of our 30 standard combinations. A little longer if you require a special type. We'll be glad to send you details and prices on request. Write today.

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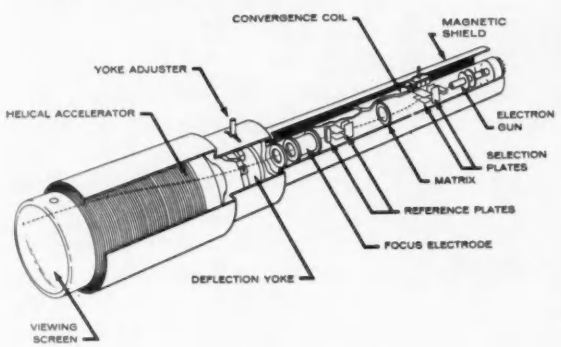
THE Bendix CORPORATION

How the CHARACTRON® Shaped-Beam Tube achieves writing speeds of 20,000 high-resolution characters a second

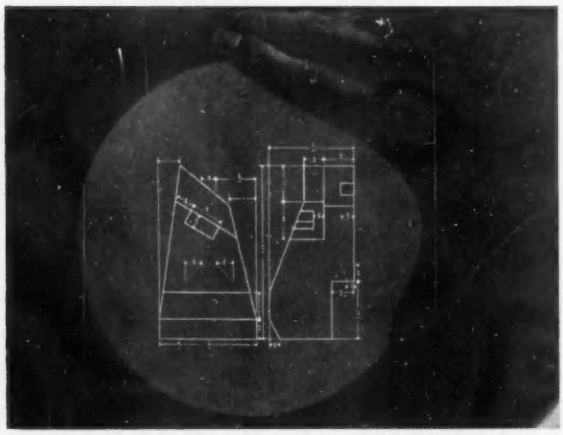
Ten years ago a small group of engineers mated the cathode-ray tube and the Magic Lantern to create a new device with almost unlimited possibilities for precision high-speed display. Systematic improvement and refinement over the past decade have created a new industry around items which were once laboratory curiosities. Today's CHARACTRON Shaped-Beam Tube, in a variety of types and sizes, is incorporated into high-speed microfilm recorders, electrostatic printers for computer data readout, and many visual situation display systems.

Among several inherent advantages of the CHARACTRON Shaped-Beam Tube is the instantaneous generation of the most complex alphanumeric characters and symbols. Character formation and generation time is not related to character complexity, as is the case with other methods. High resolution and very high speed are achieved by the beam forming and deflection methods. Characters from .75 inches to .02 inches with brightness and clarity are obtained at rates up to 20,000 characters per second.



The fundamentals of operation are basically simple. As in more conventional cathode-ray tubes, a beam of electrons is generated in an electron gun, accelerated, and introduced into a field between co-planar electrostatic plates. A special element, called the "matrix," is located at a precise distance beyond the deflection plates. The matrix is a thin beryllium-copper disc centered on the electron gun axis at right angles to the beam. Commonly, sixty-four minute characters in an 8 x 8 array are precision etched through the matrix disc. This permits selection of any character with a six-bit binary code. (Up to 256 characters have been provided for special applications.)

Applying a voltage to the deflection plates positions the electron beam at any given place on the matrix. The beam then passes through the character-shaped stencil and is returned either magnetically or by means of an electrostatic lens to the tube axis. Post-matrix reference plates and/or magnetic deflection are then employed to position the shaped beam at any desired position on the tube face.



CHARACTRON Shaped-Beam Tubes range in size from 1" x 3" rectangulars through 5", 7", 12", 19", to 21" in standard round types, with non-standard sizes available on a custom basis. Production types for slow-speed, high-speed, small-character, large-character, and variable-size character are provided off-the-shelf, depending on application and requirements. In addition to character display modes of operation, the tubes' special capabilities include line and Lissajous-figure drawing, graphical plotting, and even mechanical drawing with variable line weight for dimension and extension lines.

The cost per character of the CHARACTRON Shaped-Beam Tube in a computer readout system is less than any other comparable display device. You are invited to write for complete technical information to General Dynamics/Electronics, Information Technology Division, Dept. B-32, Post Office Box 2449, San Diego 12, California.

GENERAL DYNAMICS | ELECTRONICS

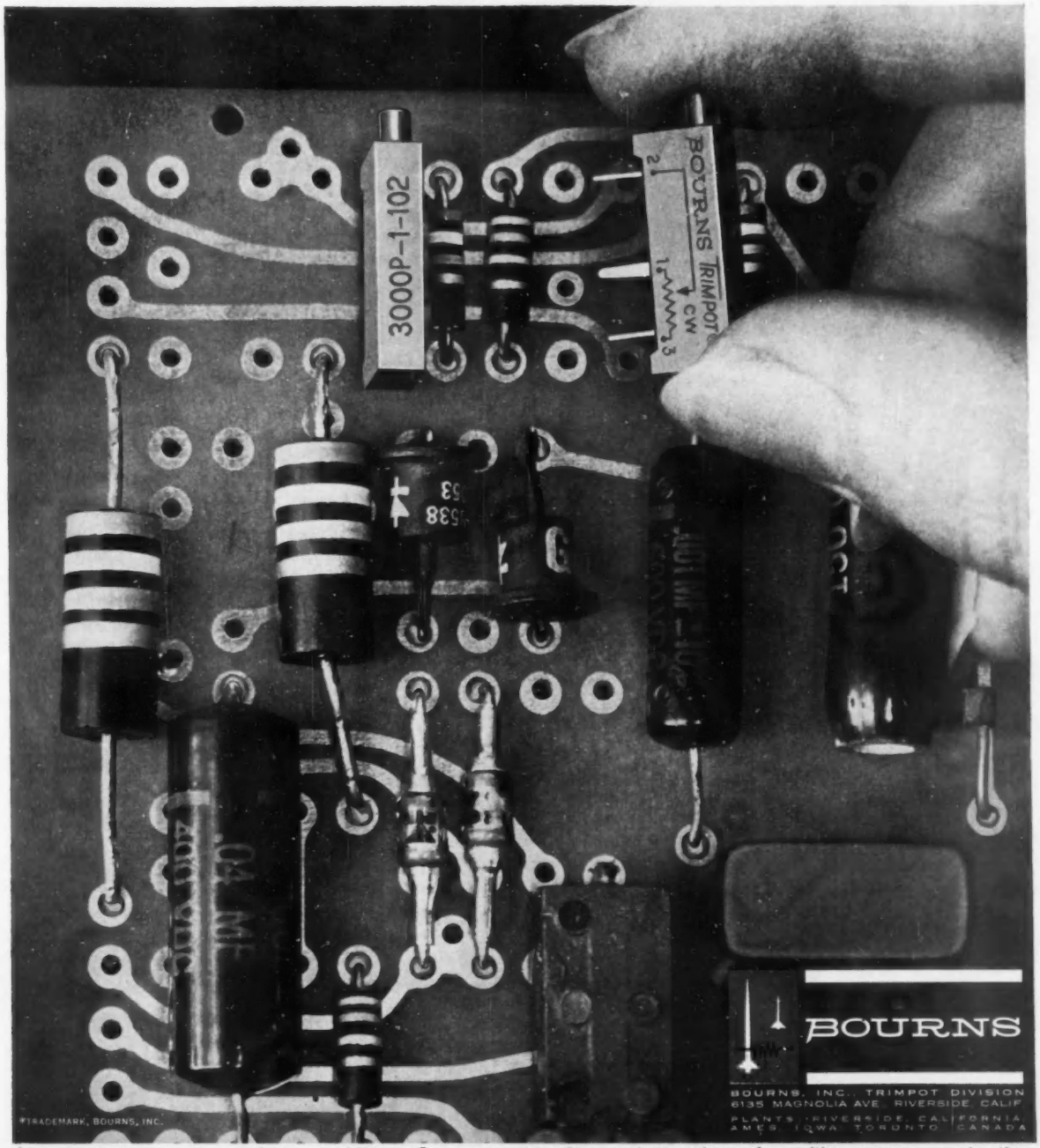
NUMBER 13—NEW PRODUCT SERIES

Now—an Even Smaller High-Temperature Trimpot® Potentiometer

Here, just ¾" in length, is a wirewound potentiometer that is completely humidity-proof and operates at 175°C! Ideal for your printed circuit applications, it withstands 30G vibration and 100G shock, dissipates 0.5 watt at 70°C (0.2 watt at 125°C), and has tapered pins for quick, easy mounting.

Sealed against humidity in a high-temperature plastic case, the Model 3000 exceeds the requirements of MIL-STD-202A, Method 106. The 15-turn screwdriver adjustment permits pinpoint settings and the self-locking shaft keeps them accurate. For maximum stability, the unit incorporates a ceramic mandrel. Reliability is outstanding. The exclusive Silverweld® bond between terminal and resistance wire is virtually indestructible under thermal or mechanical stress.

Available within 24 hours from factory and distributor stocks, the Model 3000 is stocked in resistances of 50 ohms to 20K. A Resiston* carbon version, Model 3001, is available with resistances of 20K to 1 Meg. Write for complete data and list of stocking distributors.



Exclusive designers and manufacturers of Trimpot® potentiometers. Pioneers in transducers for position, pressure, acceleration.

HOW FAR . . . AND HOW FAST . . .

can you use computer control *profitably?*

BAILEY 700 SYSTEMS CAN HELP YOU DETERMINE THIS—ONE STEP AT A TIME

Can computer control be used—profitably—in your process operations?

Where and how?

The answer often lies in intermediate stages of improvement in sensing, measuring, controlling, computing.

Bailey engineers can help you determine and prove — one step at a time — how far analog or digital systems can be profitably applied in your operations. Bailey is equipped, by broad experience, to provide single-source responsibility from sensing and measuring instrumentation to complete automation. *Bailey 700 Systems* are installed, in operation, or on order, at locations from coast to coast and throughout the world.

Find out what this Bailey background can offer. Contact your Bailey District Office.

SIX STEPS TO FULL AUTOMATION

Centralize and simplify information display—use analog and digital techniques to clarify information, aid operator understanding, improve reliability of interpretation, and save space.

Extend use of interlocks and limiting circuitry—use digital solid-state components to extend supervisory controls, thereby minimizing effects of human error.

Increase use of automatic sub-loops—simplify and standardize the starting, controlling, and stopping of major plant components and sub-systems.

Extend on-line controls—integrate sub-loops, interlocks, and limiting controls with conventional controls to secure automatic operation over full range, once unit is on the line.

Provide performance monitoring—add computing facilities to provide significant up-to-date calculations for operation improvement and maintenance scheduling.

Integrate all system elements—add start-stop control to provide full automation, the ultimate goal.

G 158-1

INSTRUMENTS, CONTROLS, AND SYSTEMS

BAILEY METER COMPANY

1079 IVANHOE ROAD • CLEVELAND 10, OHIO

In Canada—Bailey Meter Company Limited, Montreal

NOW!

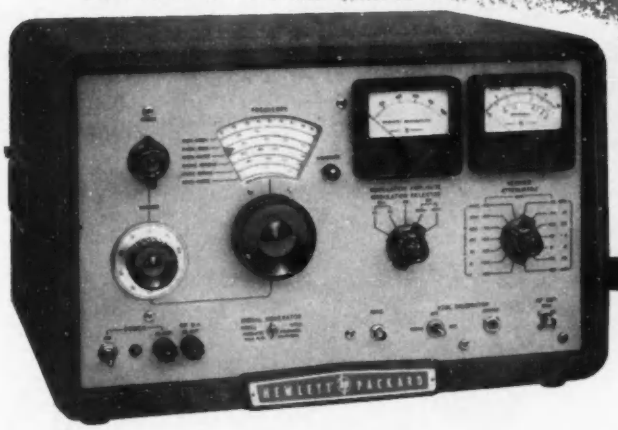
Constant output level

Constant modulation level

3 volt output into 50 ohms

Low envelope distortion

50kc TO 65MC



New -*hp*- 606A HF Signal Generator

Here at last is a compact, convenient, moderately-priced signal generator providing constant output and constant modulation level plus high output from 50 kc to 65 MC. Tedious, error-producing resetting of output level and percent modulation are eliminated.

Covering the high frequency spectrum, (which includes the 30 and 60 MC radar IF bands) the new hp 606A is exceptionally useful in driving bridges, antennas and filters, and measuring gain, selectivity and image rejection of receivers and IF circuits.

Output is constant within ±1 db over the full frequency range, and is adjustable from +20 dbm (3 volts rms) to —110 dbm (0.1 μv rms). No level adjustments are required during operation.

SPECIFICATIONS

Frequency Range: 50 kc to 65 MC in 6 bands.

Frequency Accuracy: Within ±1%.

Frequency Calibrator: Crystal oscillator provides check points at 100 kc and 1 MC intervals accurate within 0.01% from 0° to 50° C.

RF Output Level: Continuously adjustable from 0.1 μv to 3 volts into a 50 ohm resistive load. Calibration is in volts and dbm (0 dbm is 1 milliwatt).

Output Accuracy: Within ±1 db into 50 ohm resistive load.

Frequency Response: Within ±1 db into 50 ohm resistive load over entire frequency range at any output level setting.

Output Impedance: 50 ohms, SWR less than 1.1:1 at 0.3 v and below.

Spurious Harmonic Output: Less than 3%.

Leakage: Negligible; permits sensitivity measurements to 0.1 μv.

Amplitude Modulation: Continuously adjustable from 0 to 100%.

Internal Modulation: 0 to 100% sinusoidal modulation at 400 cps ±5% or 1000 cps ±5%.

Modulation Bandwidth: Dc to 20 kc maximum.

External Modulation: 0 to 100% sinusoidal modulation dc to 20 kc.

Envelope Distortion: Less than 3% envelope distortion from 0 to 70% modulation at output levels of 1 volt or less.

Spurious FM: Less than 0.0001% or 20 cps, which greater.

Spurious AM: Hum and noise sidebands are 70 db below carrier.

Frequency Drift: Less than 0.005% or 5 cps, whichever greater.

Price: (cabinet) $1,350.00. (rack mount) $1,335.00.

Data subject to change without notice. Prices f.o.b. factory.

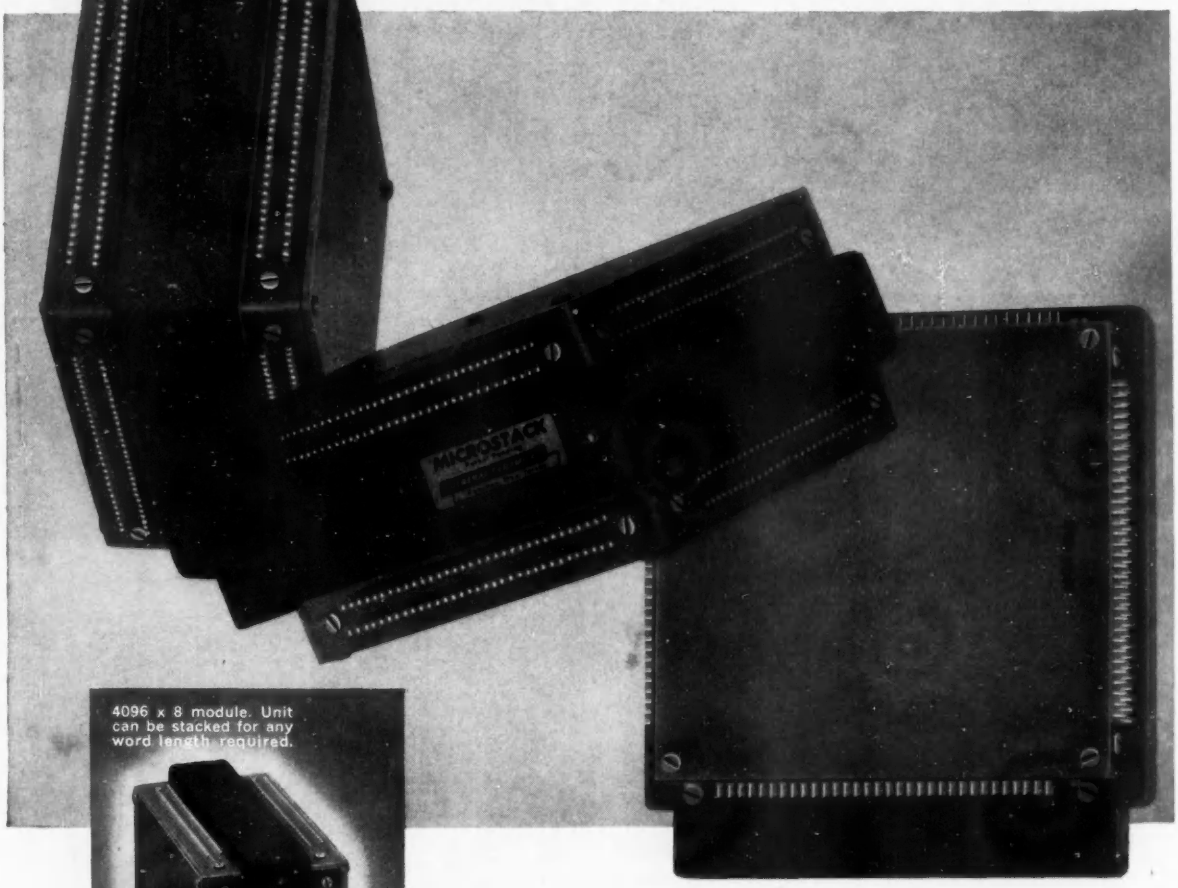
HEWLETT-PACKARD COMPANY 5023H PAGE MILL ROAD • PALO ALTO, CALIFORNIA, U.S.A.
CABLE "HEWPACK" • DAVENPORT 6-7000 • *Field representatives in all principal areas*

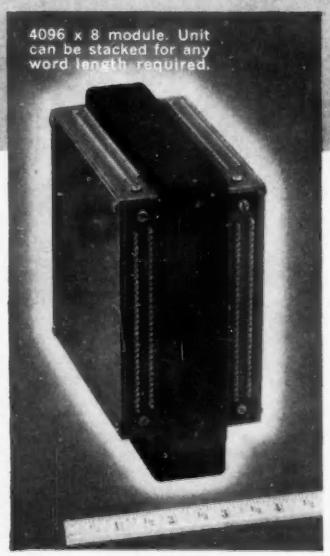
world's most complete line of signal generators

New temperature controlled MICROSTACK* meets

-55°C to +85°C

MILITARY REQUIREMENT





The General Ceramics MICROSTACK, one of the most important advances in memory core packaging, now operates in a temperature range of from —55°C to +85°C. Core characteristics remain constant. By maintaining temperature stability inside the MICROSTACK unit, General Ceramics engineers have developed a memory core package that is smaller, more rugged, requires no external cooling or heating, and meets MIL shock and vibration specifications.

For additional information, please write on company letterhead. Address inquiries to Section P-5.

DIVISION OF INDIANA GENERAL CORPORATION

APPLIED LOGIC DEPARTMENT

GENERAL CERAMICS

KEASBEY, NEW JERSEY, U.S.A.

TECHNICAL CERAMICS, FERRITE AND MEMORY PRODUCTS

Just *Plug it in*

any computer and...

- **multiply**
- **divide**
- **square**
- **extract square root**

Donner's new all solid state electronic multiplier plugs into any analog computer problem board with ¾" terminal spacing — all Donner models, all Heathkit models, Boeing (BEAC), Goodyear L3-N3 series, and so forth.

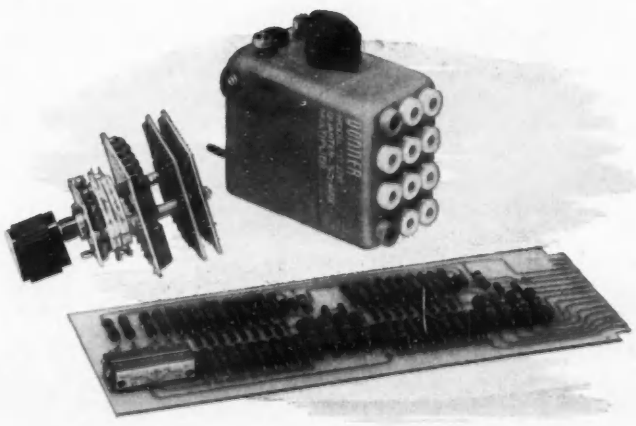
Designed on the quarter-square principle, this compact, single channel multiplier offers four modes of operation selected by a switch:

- Four-quadrant multiplication (output = $-0.01XY$), with static accuracy of 0.3% of full scale voltage (200 volts).
- Two-quadrant division (output = $-100X/Y$).
- Two-channel squaring (outputs of $-0.01X^2$ and $+0.01Y^2$).
- Two-channel square root operation.

As inputs, the Model 3732 accepts +X, −X, +Y, −Y, and generates an output current to the summing junction of an external amplifier.

To satisfy your particular needs, Donner furnishes the multiplier in a variety of packages besides the plug-in version shown.

Model 3732 electronic multiplier is available without enclosure for panel mounting or as a single printed card for inclusion in your system. The unit is also available with up to three solid state multipliers on a 3½" x 19" panel for rack mounting.

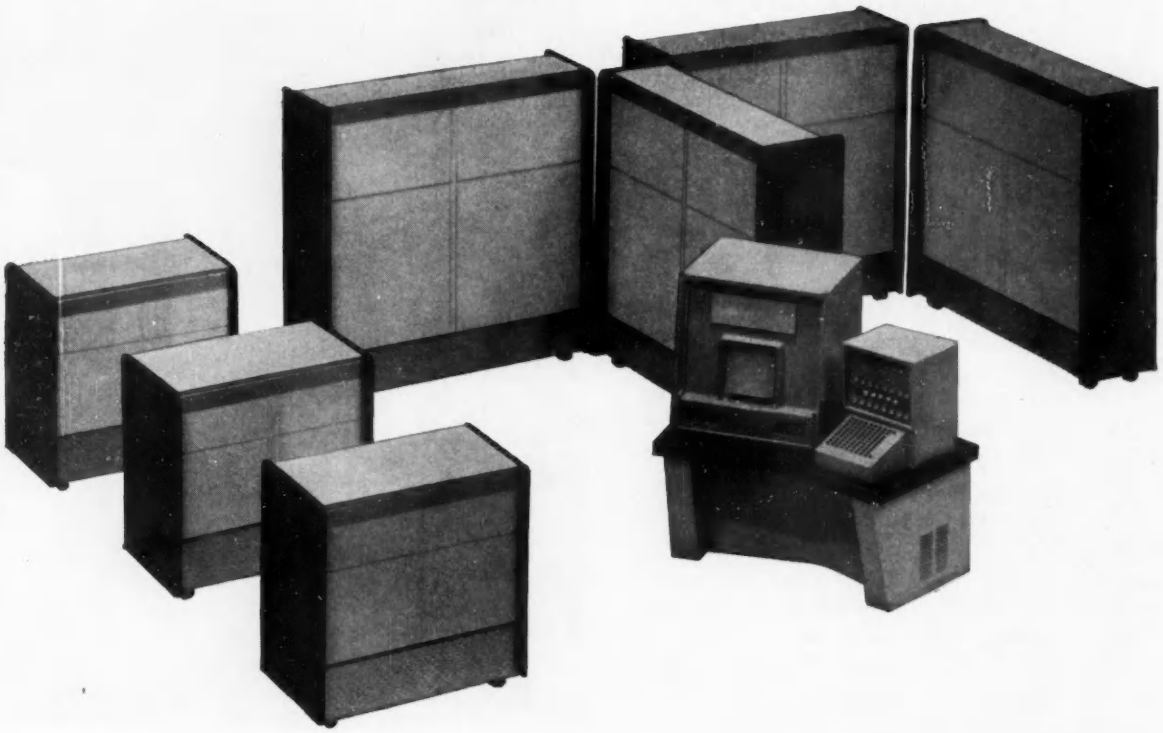


Price of the Model 3732P is $350; delivery 30 days. Other prices, detailed specifications and demonstrations available from all Donner representatives or just drop us a line at the factory. Please address Dept. 21

DONNER
SCIENTIFIC COMPANY
A SUBSIDIARY OF SYSTRON-DONNER Corporation
CONCORD, CALIFORNIA

CIRCLE 51 ON READER SERVICE CARD

LFE's new RD-900 system--



. . . provides a random access file of up to 495 million bits with access to information in less than 3/10 of a second.

. . . may be operated with all standard general purpose digital computers, or as an independent storage, access and display system.

The RD-900 Random Access Storage and Display System, consists of from 1 to 33 high density, magnetic, file drums, each with a storage capacity of 15 million bits. A Symbol Generator converts coded characters into a visual message as fast as they are read from the file. One Symbol Generator is used to drive any number of output display devices. These include 21" console displays and large screen projection displays . . . each capable of displaying up to 12,800 characters, symbols or a composite of both. In addition to alphanumeric characters the system can display arbitrary or abstract symbols, schematic or logical drawings, graphs, charts, and maps. Applications include military and industrial systems where information retrieval and display must be simultaneous for instant decision making. For a complete description and specifications write Dept. 101.

LFE
COMPUTER PRODUCTS DIVISION

LABORATORY FOR ELECTRONICS, INC.

1079 COMMONWEALTH AVE. • BOSTON 15, MASSACHUSETTS

See a demonstration—Western Joint Computer Conference—May 9-10-11
Ambassador Hotel, Los Angeles

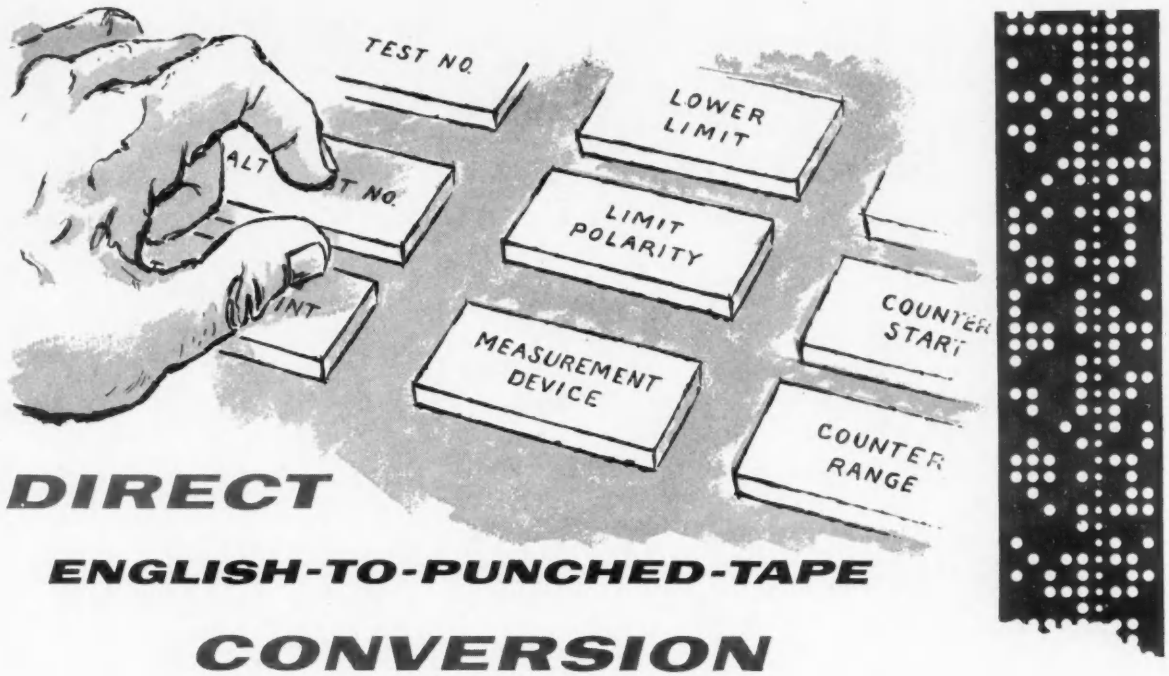
ARMA

PRODUCING ALL-INERTIAL GUIDANCE FOR ATLAS

Many successful full-range test flights have proved the reliability and accuracy of the Arma inertial guidance system now in full production. Other advantages—salvo firing, immunity to jamming, low cost, a minimum of ground support equipment—are inherent in inertial guidance. Currently at Arma, company-funded research programs are studying smaller, super-sensitive devices for navigation and satellite instrumentation.

ARMA, Garden City, New York, a division of American Bosch Arma Corporation . . . the future is our business.

AMERICAN BOSCH ARMA CORPORATION



DIRECT ENGLISH-TO-PUNCHED-TAPE CONVERSION

The McDonnell TAPE* automatically prepares punched tape. TAPE's logic circuitry electronically analyzes word-group and numerical keyboard commands and converts them to complete coded programs. Punching mechanisms instantly deliver the finished tape. Editing, verifying, duplicating or correcting is accomplished quickly and automatically.

TAPE Slashes Time and Costs

Programming time, operator training, schedule delays, as well as large computers, key punches and other peripheral equipment are eliminated. Small size permits installation in laboratories or wherever finished tape is used. Unskilled operators learn to use TAPE in minutes. The McDonnell TAPE has demonstrated the capability to prepare 25,000 feet of perfect tape at less than half the cost and in less than one-third the time required to prepare the same tape with the best standard computer preparation method available.

A prototype McDonnell TAPE is operating which prepares tape for the AN/GJQ-9 missile and aircraft automatic checkout system. Minor modification readily adapts the keyboard and logic circuitry to tape preparation requirements of other industrial and military operations.

Whatever your punched tape requirements, you are invited to visit McDonnell and operate TAPE.

Tape Automatic Preparation Equipment

For descriptive literature, write:

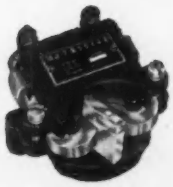
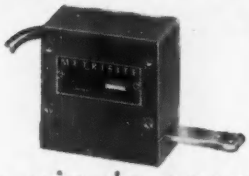
Electronic Equipment Division
Dept. 952
McDonnell Aircraft, St. Louis, Missouri

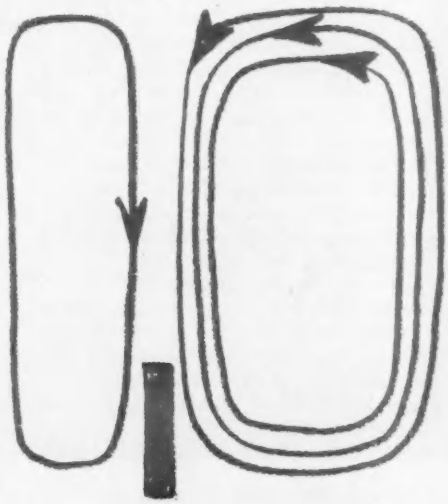
MCDONNELL

ELECTRONIC EQUIPMENT DIVISION

Airborne Antennas • System Trainers • Simulators • Radio Beacons • Telemetry • Specialized Digital Computers • Microwave Components • Automatic Flight Control Systems • Automatic Checkout Equipment

MCDONNELL AIRCRAFT • ST. LOUIS

Metrisite... is the only  device available today that provides a near-perfect combination of ideal transducer characteristics. The unusual properties of this remarkable new motion-sensing development are: extreme resolution...  easily measures one ten-millionth of an inch; minute operating force... absolute minimum bearing friction; negligible reactive force... a fraction of a milligram; true linearity... a proven accuracy of 1/10%; high electrical output... up to 100 volts without amplification; wide range of shapes and sizes... from sub-miniature on up; exceptional ruggedness... can meet military shock and vibration tests. Now, many of the obstacles that have plagued control technology can be eliminated. Write for Metrisite details.

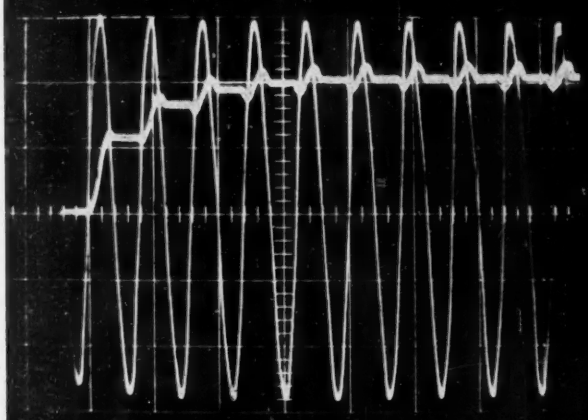


brush INSTRUMENTS
DIVISION OF
37TH AND PERKINS CLEVITE CORPORATION CLEVELAND 14, OHIO

CIRCLE 55 ON READER SERVICE CARD

AC MEASUREMENT

FAST AND PRECISE



FAST ACQUISITION

Superimposed input and output waveforms show the fast response time of Adage's Type ACS1 AC Averager. Short filter time constant allows the steady state value to be achieved quickly.

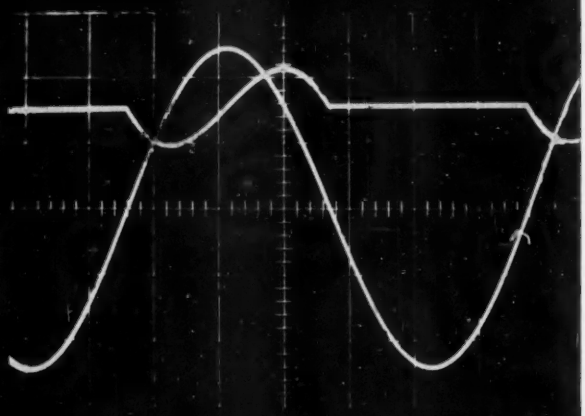
PRECISE MEASUREMENT

The ripple present in the output waveform does not interfere with the precision of the measurement. Timing circuitry insures that the voltage measured is that value present during the interval when the output is ripple free.

Modern instrumentation systems demand equipment to make fast, precise measurements of AC signal waveforms. This required combination of speed and accuracy is beyond the capability of conventional techniques. For example, a conventional diode-capacitor AC/DC converter requires at least three seconds settling time to make 60 cps measurements. When many different signal sources must be scanned and measured successively, this slow response time limits seriously the overall system speed.

Slow response time is also a disadvantage in AC carrier systems. The transformer-driven diode bridge demodulators conventionally used as phase-sensitive AC measurement instrumentation for these systems have inherent limitations in both speed and accuracy. They tend to compromise the performance of instrumentation systems using them.

There has been, then, a clear need for innovation in the field of AC measurement. Responding to this need, Adage has developed several new AC measurement techniques. Among these is the fast-averaging technique illustrated in the accompanying waveform photographs. This technique offers substantially improved performance both for self-synchronous and phase-sensitive measurements. Response time, for example, is improved by more than a factor of ten to one. Used in conjunction with precision voltage to digital converters, modules implementing these new measurement methods have been successfully applied in many industrial and military instrumentation systems. A typical solid-state, AC Signal Conditioner is comprised of three 5″ x 8″ epoxy fibreglass circuit modules, easily incorporated in any of the Adage VOLDICON® voltage to digital converters.



Applications notes and technical data describing in detail Adage's AC instrumentation capability is available upon request.

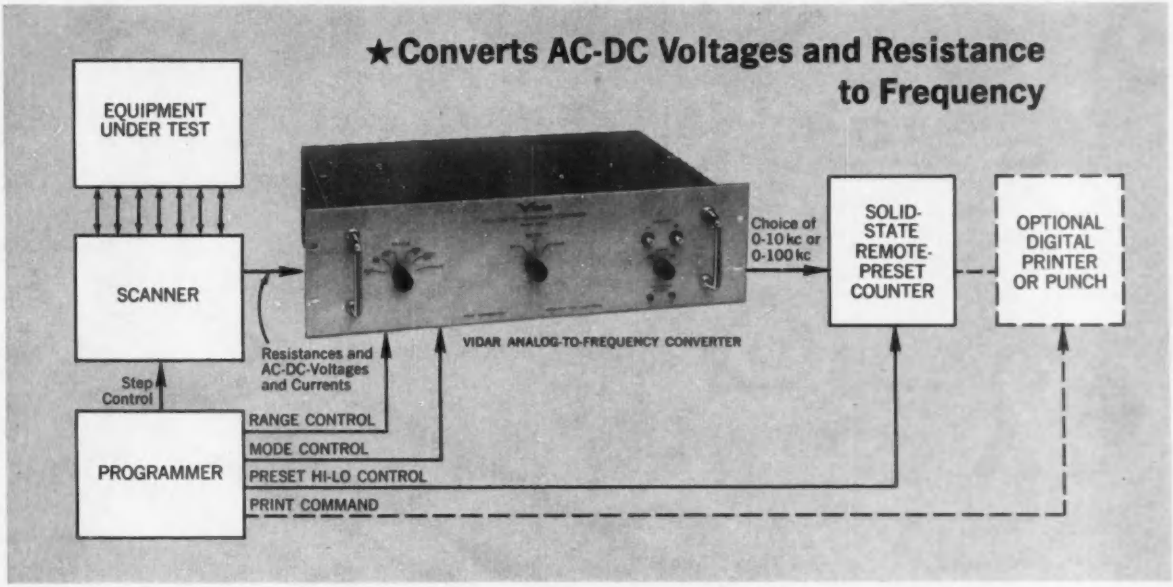
Adage INC

292 MAIN ST., CAMBRIDGE 42
MASSACHUSETTS

West Coast Facility: 1145 East Ash Avene, Fullerton, California

Solid State Solution to Automatic Checkout

Announcing the VIDAR 2500 Analog-to-Frequency Converter



Missing link in applying digital techniques to automatic checkout has long been an accurate and flexible means of converting electrical parameters to digital form. The new Vidar 2500 closes the chain of measurement solidly, economically and reliably.

Combined with a counter, a Vidar 2500 analog to frequency converter provides direct digital readout of basic electrical parameters. Adding a printer makes a low cost digital data logger. Using a preset counter, the system becomes a go-no-go, hi-lo, in or out of limits tester. Remote control capability of the converter enables an external programmer to control its range and mode.

Applications for this kind of system include production checkout of components and systems, experimental data acquisition, component sorting, and quality control testing. As illustrated by the diagram, automated testing can be accomplished by combining an input scanner, Vidar converter, preset counter and printer with an automatic programmer which advances the scanner and printer, controls range and mode on the converter, and sets high and low limits on the counter.

Vidar 2500 converters develop output pulses at a rate precisely proportional to voltage or resistance. Almost any group of electrical parameters can be automatically checked with the basic low cost combination of a Vidar converter and an electronic counter. Other systems either require expensive digital comparators to do the same job or cannot read all the electrical parameters.

KEY TECHNICAL FEATURES

- * Manual or Remote Range and Mode Selection
- * Automatic Polarity Indication
- * Full-Scale AC and DC Sensitivities from 0.1v to 1000v
- * 1 K to 10 Meg Resistance Ranges
- * Solid-State Circuitry—No Vacuum Tubes
- * 0.1% Accuracy for DC and Resistance, 0.5% Accuracy for AC from 50 cps to 100kc
- * Counted Output is Proportional to Integral of Input Giving Inherent Noise-Averaging Property.
- * Choice of 0-10kc or 0-100kc Frequency Outputs
- * Floating Input, Isolated from Rack and Output Grounds
- * Low Cost — $1,500 to $2,500, depending on options

FOR A DEMONSTRATION

Call your nearby Vidar engineering representative or write directly to the factory for complete technical information.

VIDAR CORPORATION

2296 Mora Drive
Mountain View, California
Phone: YOrkshire 8-6561

VIDAR ENGINEERING REPRESENTATIVES

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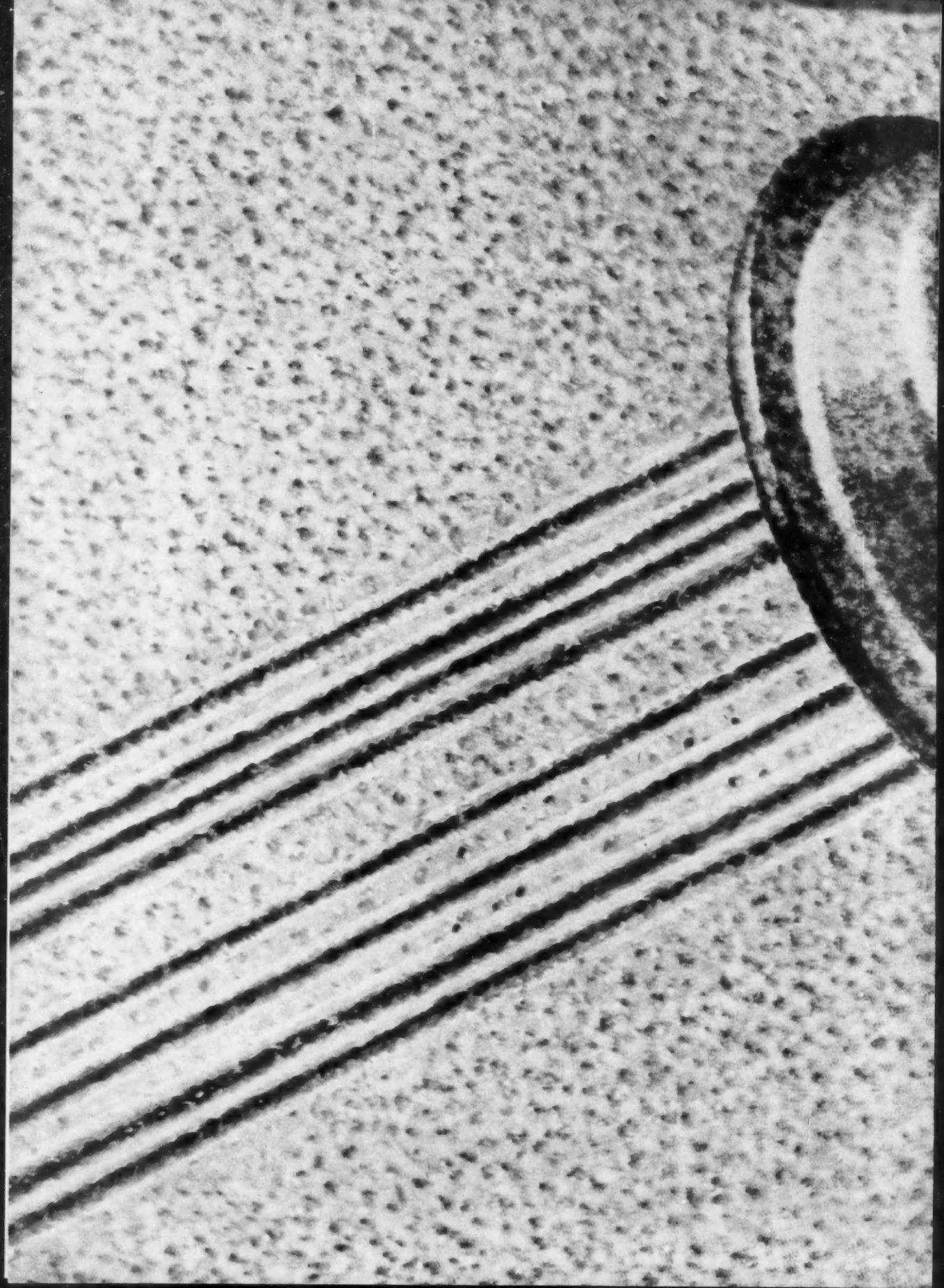
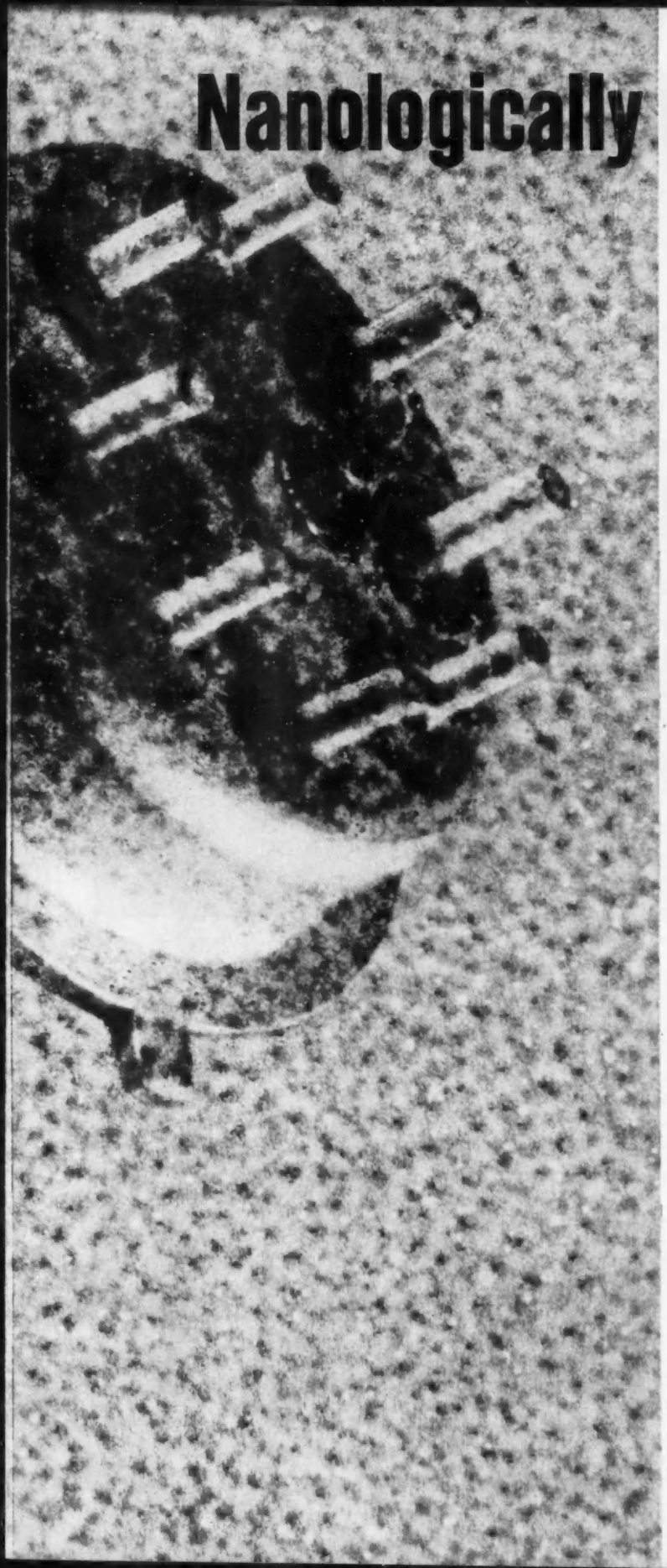


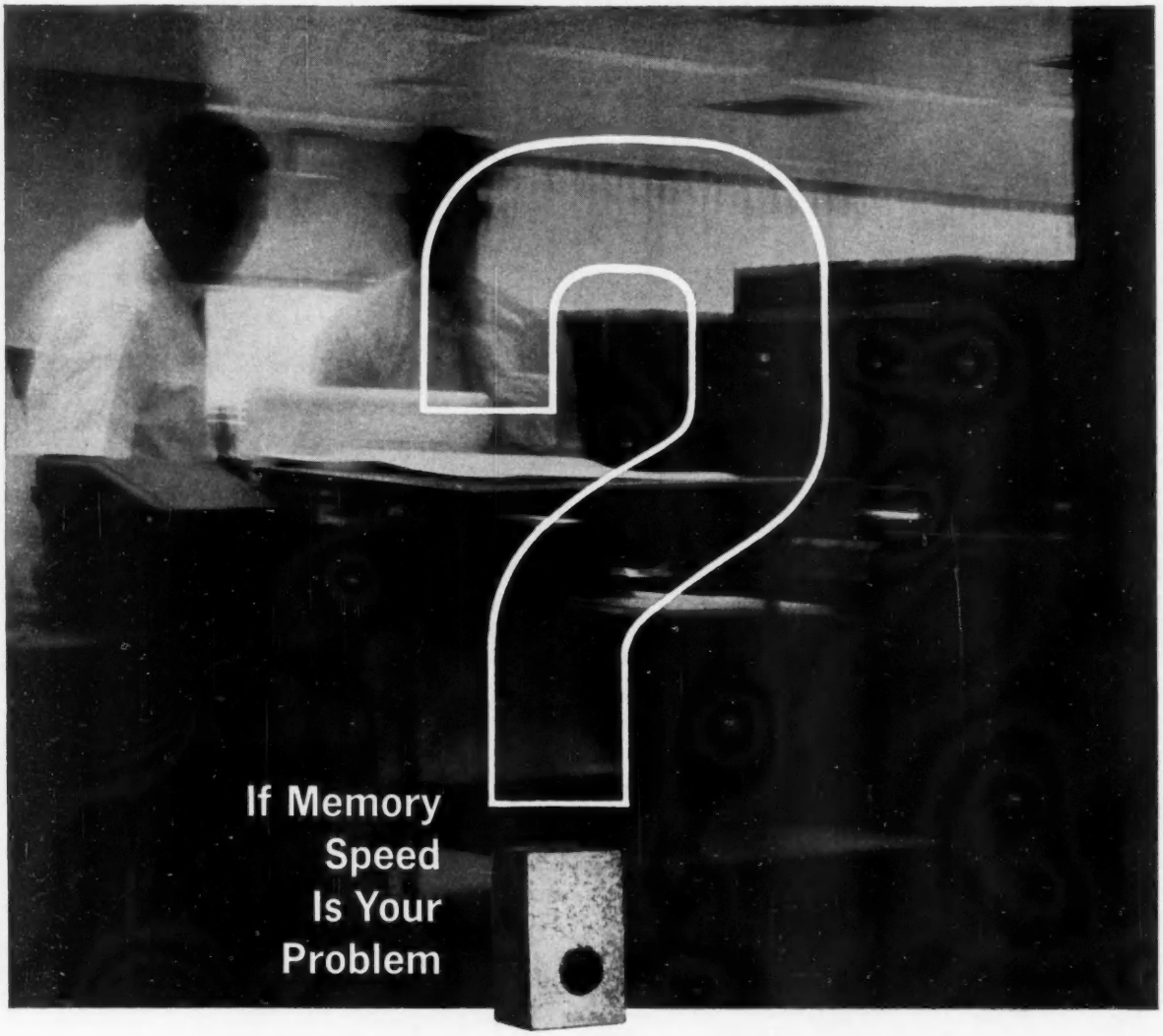


Nanologically speaking

THINK ABOUT IT: Six diodes interconnected in a single, standard-size transistor can. General Instrument Research Labs thought about it . . . then produced it along with a whole new array of computer logic "nanocircuits" that offer unusual design flexibility. ■ The General Instrument concept permits nanocircuits to be transferred directly to conventional-component circuitry. This approach frees the circuit designer of the limitations of ordinary microcircuitry. And, because the heat-generating elements are kept outside the can, circuit reliability is increased. ■ It is this applied imagination, which General Instrument brings to all semiconductors, that underlines the distinction between rhetoric and reason. ■ Get specific details about General Instrument nanocircuits from one of our sales offices or the franchised distributor nearest you. Or write for Bulletin NC-10. General Instrument, Semiconductor Division, 65 Gouverneur Street, Newark, New Jersey.

GENERAL INSTRUMENT SEMICONDUCTOR DIVISION

CIRCLE 59 ON READER SERVICE CARD



BIAX MEMORIES are the answer

Aeronutronic's BIAX INSTRUCTION MEMORIES will increase the speed of your computer, data handler, or control system. These remarkable memories operate at high speed, with non-destructive read, low power, and high reliability.

BIAX MEMORIES offer access time of 0.4 μsec and cycle time of 1.0 μsec without need for regeneration. These advanced memory systems will give you the necessary speed and reliability for all your program storage.

BIAX MEMORIES are available in several standard sizes or can be built to your specifications on a fixed price basis. Their low power requirements plus high reliability over a broad range of environmental conditions assure dependable performance.

For further information regarding BIAX MEMORIES' capabilities applicable to your requirements you are invited to write or call: Manager of Marketing, Computer Products Operations, Department 28.

Specifications

Up to 1024 words
Up to 36 bits per word
Read cycle time: 1.0 μsecond
Access time: 0.4 μsecond
Loading: From paper tape or your equipment at rates up to 200 kc
Power: Less than 50 watts
Temperature: 0°C to 50°C

AERONUTRONIC
DIVISION
Ford Motor Company
NEWPORT BEACH, CALIFORNIA

INLAND

first with solid state 100-watt d-c amplifier

Inland's new **Model 579.35** d-c amplifier has a high power output of 100 watts when used with low impedance loads requiring direct current. And this completely transistorized amplifier is packaged in a hermetically sealed can only **2½" x 3¾6" x 2½"**.

Designed for use with d-c torquers, in one typical application Model 579.35 provides 65 db power gain between the output of a d-c driver stage and the input terminals of a permanent magnet torque motor. This amplifier has these outstanding performance characteristics:

- The d-c output has magnitude and polarity proportional to the input signal.
- All amplifier circuits use a combination of silicon and germanium transistors (all-silicon models also available).
- Amplifier null and gain are stable and independent of temperature.

Inland also makes a complete line of rotary amplifiers for matched use with Inland's distinctive pancake shape d-c torquers.

A brochure on this new high-power amplifier is available. For your copy and complete data on Inland torquers and amplifiers, write Dept. 5-5.

TYPICAL SPECIFICATIONS

Maximum Power Output, watts (6 ohm load)	100
Power Gain	4,000,000
Current Gain	200,000
Voltage Gain	15
Frequency Response	DC to 1000 cps
Input Impedance, ohms	50,000
Dimensions, inches	2½ wide 3¾6 long 2½ high
Operating Temperature Range in °C	minus 50° to plus 50°

INLAND MOTOR

INLAND MOTOR CORPORATION OF VIRGINIA • A SUBSIDIARY OF KOLLMORGEN CORP., NORTHAMPTON, MASS.

Here lie 707 rolls of paper tape shot full of holes by Tally Perforator #171

...Long may she run!

LIFE TESTING PROVES RELIABILITY OF TALLY READERS AND PUNCHES

The only way to really find out if a machine is reliable is to run it to death. That's what Tally engineers are literally doing with perforator #171 as part of a continuing program to prove and improve the accuracy and reliability of Tally tape equipment.

On October 20, 1960, perforator #171, chosen at random from a production run, started a life test with an alternate hole pattern verified by a Tally reader.

As of Feb. 13, 1961, perforator #171 had completed 70,700,000 cycles of accurate operation with only two minor mechanical break-downs. Repairs were made in a matter of minutes. This is a record of reliability that speaks for itself.

RELIABILITY IS ONE REASON TO CHOOSE TALLY

"State of the art" technical excellence is another. Only Tally punches give you the benefit of asynchronous operation. Speed is completely variable. A unique wire clutch lets you vary speed for slaving to other equipment which simplifies the design of logical systems.

Tally punches are priced from $1,000. Standard perforators operate at 60 characters per second and will punch 5, 6, 7, and 8 channels without modification. On special order up to 32 channels are available.

Only Tally readers give you the benefits of "full bit accountability." Using Form C switching, you get positive sensing of the presence or absence of holes. Reading rate is 60 cps in either direction – instantly reversible for rapid search and select. Readers have triggered tape feed readout with the rate controlled by external equipment. Reader prices begin at $595 for standard units capable of reading 5, 6, 7, or 8 channels without modification.

FOR A DEMONSTRATION OR MORE INFORMATION

You may arrange a demonstration or secure full technical information by calling your nearest field engineering office listed below or writing directly to factory.

P.S. *If you are having problems making complex multichannel programming tapes, call us about that too. We're making up 16 channel guaranteed error-free tapes for some of the nation's most sophisticated missile and satellite programs.*

TALLY

REGISTER CORPORATION

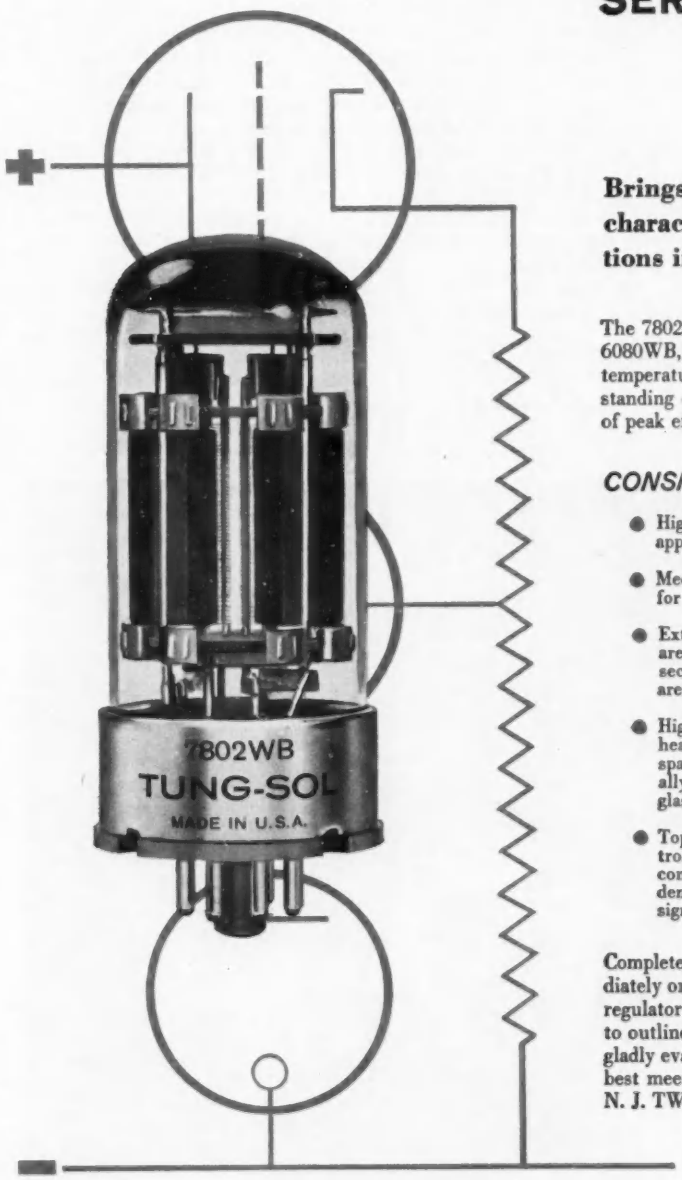
1310 Mercer Street • Seattle, Washington

Phone: MAin 4-0760

TALLY FIELD ENGINEERING OFFICES: ATLANTA, Georgia, TRinity 3-2475 • **BOSTON (Framingham) Massachusetts,** TRinity 2-2061 • **CEDAR RAPIDS, Iowa,** EMpire 5-6183 • **CHICAGO, Illinois,** KEystone 9-4838 • **CINCINNATI, Ohio,** BLackburn 1-2349 • **CLEVELAND, Ohio,** TUxedo 6-3535 • **DAYTON, Ohio,** BALdwin 3-9621 • **DENVER, Colorado,** SKyline 6-9455 • **DETROIT (Southgate) Michigan,** AVenue 5-3125 • **FORT WORTH, Texas,** WAlnut 6-4444 • **HOUSTON, Texas,** MAdison 3-4112 • **HUNTSVILLE, Alabama,** JEfferson 9-5552 • **IDAHO FALLS, Idaho,** JA 2-992 • **INDIANAPOLIS, Indiana,** VIctor 6-1532 • **KANSAS CITY, Missouri,** JEfferson 1-7765 • **LOS ANGELES (La Canada) California,** SYlvan 0-3195 • **NEW YORK (Roslyn, Long Island) New York,** MAyfair 1-8660 **ORLANDO, Florida,** GArden 4-0730 • **PHILADELPHIA (Southampton) Pennsylvania,** LOcust 8-7078 • **SAN FRANCISCO (Palo Alto) California,** DAvenport 3-0128 • **SEATTLE, WASHINGTON,** EAst 3-8545 • **ST. LOUIS, Missouri,** PArkview 6-2233 • **ST. PAUL, Minnesota,** Midway 6-3443 • **WASHINGTON, D.C. (Arlington) Virginia,** JAckson 4-2272 • **WICHITA, Kansas,** MUrray 3-3751 • **WINSTON-SALEM, North Carolina,** PArk 3-3281.

10

TUNG-SOL ANNOUNCES:



NEW MEDIUM-MU
SERIES REGULATOR TUBE
7802WB

Brings together an optimum combination of characteristics that makes it ideal for applications in tough environmental extremes.

The 7802WB twin-triode, medium MU companion to the popular 6080WB, is the newest in the broad Tung-Sol line of rugged, high temperature, long-life series regulators. It combines many outstanding operational and design features in an optimum package of peak efficiency and dependability.

CONSIDER JUST THESE FEATURES:

- High perveance . . . Makes the 7802WB an excellent choice for applications requiring high plate current at low plate voltage.
- Medium-mu . . . Makes only very small signal voltages necessary for precise 7802WB control.
- Extra-tight tolerances . . . Plate current and transconductance are held to rigid limits to provide greater balance between tube sections. This is of particular significance where many sections are operated in parallel.
- High temperature operation . . . Extensive use of ceramics for heater-cathode insulators, anode standoff insulators and element spacers. The graphite anodes used are warp-free and dimensionally stable regardless of operating temperatures. Non-char, glass-bonded mica material is employed in the tube base.
- Top-performance in environmental extremes . . . Where electronically regulated power supplies must perform under severe conditions of shock vibration and high altitude, the 7802WB demonstrates long, trouble-free life, assured by both tube design and specifications.

Complete technical details on the 7802WB will be furnished immediately on request. A description of the full-line of Tung-Sol series regulator tubes is also readily available. Tung-Sol also invites you to outline your design needs to us. Our application engineers will gladly evaluate your circuit and outline the component which will best meet your requirements. Tung-Sol Electric Inc., Newark 4, N. J. TWX:NK193

TUNG-SOL®

Technical assistance is available through: Atlanta, Ga.; Columbus, Ohio; Culver City, Calif.; Dallas, Texas; Denver, Colo.; Detroit, Mich.; Irvington, N. J.; Melrose Park, Ill.; Newark, N. J.; Philadelphia, Pa.; Seattle, Wash. In Canada: Abbey Electronics, Toronto, Ont.

CIRCLE 63 ON READER SERVICE CARD 63

Here's Take-Your-Choice Versatility

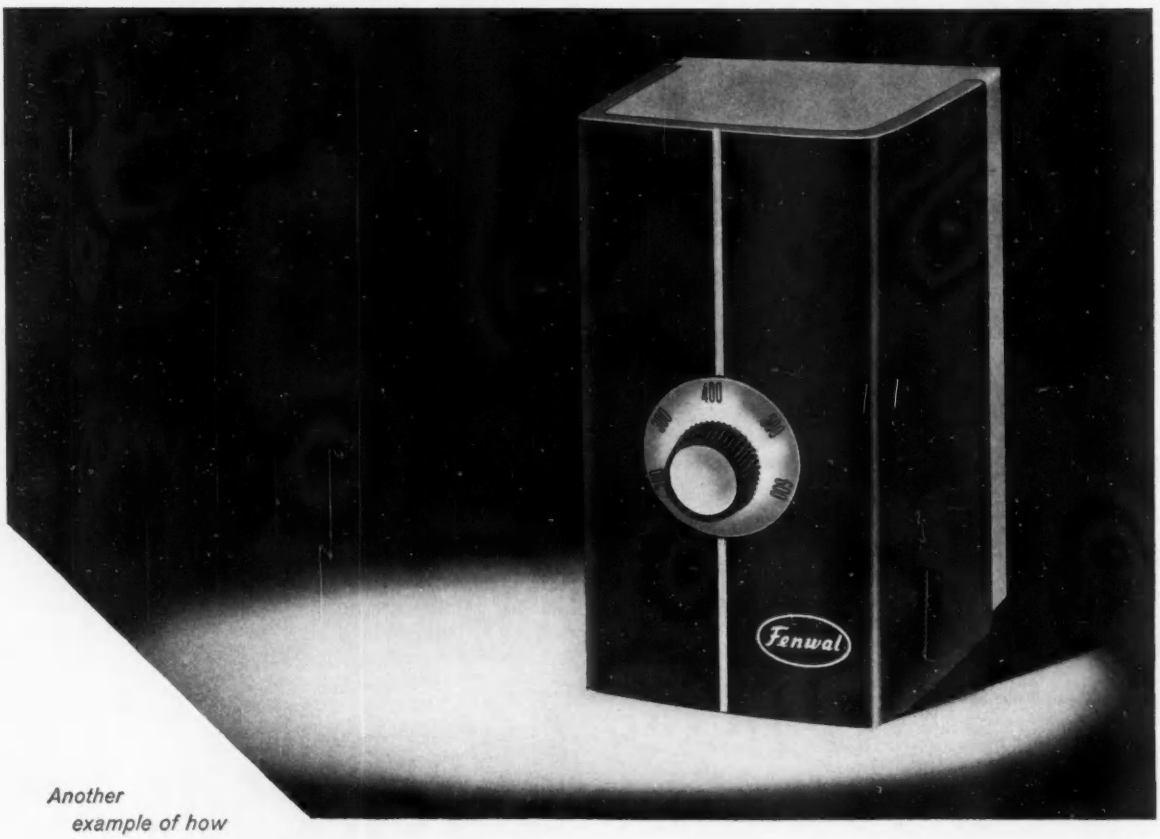
with the Multi-option Fenwal 536 Temperature Controller

It's so *precise* and yet so *easily adaptable* to an almost endless variety of temperature control applications, you become all but convinced that the transistorized Model 536 was engineered with only your needs in mind!

From its multi-option printed circuit board to its numerous interchangeable components, the Model 536 Temperature Controller spells *versatility*. ON/OFF or proportioning control . . . dial for set point adjustment mounted externally or internally . . . expanded scales for precise temperature adjustment — the 536 offers all these advantages! Five standard temperature ranges from −50 to +600°F . . . separate potentiometer with graduated dial and knob for remote temperature adjustment . . . capacity of 10 amp/110 VAC and 5 amp/230 VAC . . . these choices are also available to you. *And you pay only for the options you need!*

The 536 is sensitive to within 0.1F°. And if you wish to build a multi-point control and indication system — either gradually or all at one given time — you simply combine the Fenwal Model 580 Temperature Indicator with as many 536 Controllers as you require. Thermistor sensors enable fast response and ordinary copper lead wire may be used for connections. Removable interior of the Model 536 allows easy, safe installation and the instruments are smartly styled to perfectly complement modern industrial machines and interiors.

Find out more about how the precise Model 536 Temperature Controller can be adapted to your exact needs by writing to FENWAL INCORPORATED, 295 Pleasant St., Ashland, Mass. Request Bulletin MC-195.

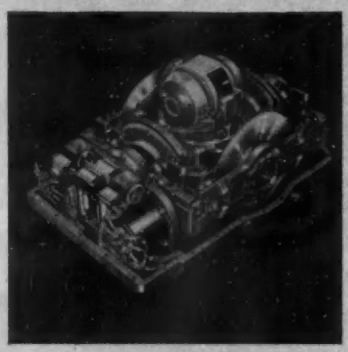


Another example of how

Fenwal CONTROLS TEMPERATURE . . . PRECISELY

LITTON ADVANCED INERTIAL PLATFORM FEATURES TWO UNIQUE, FLOATED TWO-DEGREE-OF-FREEDOM GYROSCOPES

The use of two floated two-degree-of-freedom gyros simplifies the inertial platform, provides higher accuracy and reduced size and weight. Selecting two two-degree-of-freedom gyros as compared to three single-degree-of-freedom gyros was done to increase the accuracy by taking advantage of the larger available space per gyro and to eliminate the undesirable rectification drift inherent in the single-degree-of-freedom gyro platform. It also provided for tighter packaging and simplified design, which contributes to the total platform accuracy, yet permits considerable reduction in size and weight.



To achieve the development of the Litton platform, consideration had to be given to entire new concepts in inertial components, design, packaging, production and testing techniques. Litton developed a unique two-degree-of-freedom gyro measuring three inches in diameter, four inches in length, and weighing only two pounds, that provides a random drift rate capability of less than 0.01 degrees per hour. The two gyroscopes used are packaged in a "dumbbell" configuration which is retained in a four-axis gimbal mechanism. This permits unrestricted angular maneuverability of the vehicle without incurring platform gimbal-lock.

Another Litton developed component contributing to the design of the platform is a miniature accelerometer featuring a pendulous torque-balance mechanism. The accelerometer functions by means of external electronic integrating circuitry, thus eliminating the complexity and larger size of internal integrating devices. The use of nonintegrating accelerometers contributes to the compactness and light weight of the platform. The accelerometer measures only 1.00 x 1.135 x 1.80 inches and weighs 7 ounces.

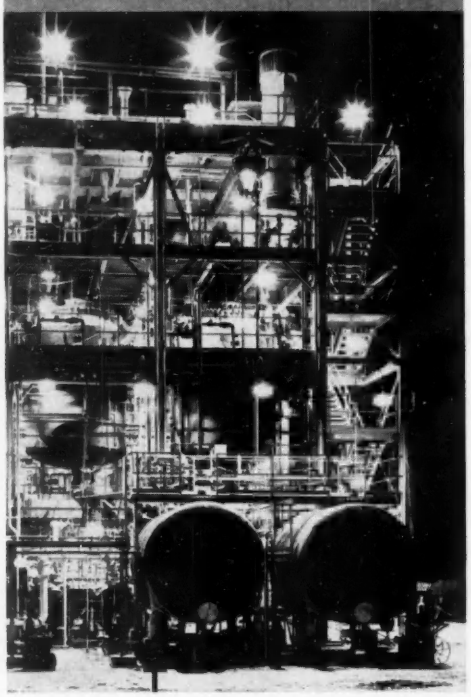
Three identical orthogonally mounted accelerometers are used. The accelerometers, through stabilization signals received from the gyroscopes acting on the platform servos, provide simultaneous measurement of vehicle acceleration along three axes.

If you're in the inertial or electronic field, it may be that a few of these points have sparked your imagination; it may be that Litton is the place for you to contribute your ideas to advanced projects. Advances in the state-of-the-art in all our areas of interest are lining up chairs of responsibility for the engineer capable of contribution. For the engineer who wants more engineering, less paper work. For the engineer with plans ... who wants to see a job through from concept to product.

Our product is inertial equipment, computers, data processing systems, tactical data systems, displays and advanced communications techniques. If working on these kinds of projects and in this kind of atmosphere interests you, write today to Mr. Donald Krause, Research and Engineering Staff, Litton Systems, Inc., 336 No. Foothill Road, Beverly Hills, California.

LITTON SYSTEMS, INC.
Beverly Hills, California
DIVISION OF LITTON INDUSTRIES

A leading Chemical Company uses versatile ISI 609 Information and Computer Systems



609

Practical information for profitable control

Integrated with the master control room, ISI's 609 provides both process operators and supervisors with a valuable silent partner. Over 400 variables are continuously scanned for automatic display and alarm detection. System flexibility includes data reduction, computation and fully automated process control.

With over 130 installations in utilities and process plants, Information Systems, Inc. offers 11 years of experience in all phases of industrial data gathering, information display and computer information systems. ISI's completely integrated service is backed by proven hardware. ISI Information Systems guarantee practical information and exceptional versatility. Will your future control system supply useful, meaningful information immediately? Will it improve plant efficiency and product quality with economic feasibility? Will it furnish closed loop, fully automated control? *Evaluate ISI before you buy. Write for capability and case history data, or contact your nearest ISI office.*

YOUR BEST INVESTMENT IN POWER AND PROCESS CONTROL • INFORMATION HANDLING • INDUSTRIAL AUTOMATION • NATURAL GAS DISPATCHING

INFORMATION SYSTEMS, INC.

SYSTEMS DIVISION

10131 NATIONAL BOULEVARD, LOS ANGELES 34, CALIFORNIA

Regional Offices in New York City · Chicago · Houston · Los Angeles

ISI INFORMATION SYSTEMS IS OUR BUSINESS

a new concept in compactness

SANGAMO 460-SERIES MAGNETIC TAPE INSTRUMENTATION

The Sangamo 460-Series is not just another tape transport, but a magnetic tape recorder/reproducer so compact that it can contain a complete 14 track record-reproduce system in one standard 19″ w. x 71″ h. cabinet. All its read, write, speed control, and power supply circuits are transistorized and grouped into modules on individual, plug-in circuit boards. It is designed for reel-to-reel or loop operation in direct analog, FM, PDM, and PCM modes.

In the 460-Series transport, record and reproduce circuit boards are located directly above the control panel at eye level to permit easy access for signal level adjustment and monitoring without interfering with system operation. All DC power for the transport and record-reproduce electronics is provided by a modular sub-assembly mounted at the bottom of the cabinet. The complete power supply is mounted on drawer slides.

› Magnetic tape instrumentation system accuracies heretofore considered unattainable have been achieved by Sangamo as a result of reduced instantaneous and long-term record-playback speed deviations. The 460-Series Recorder/Reproducer accomplishes this by combining a very low inertia DC capstan drive with a high-response, tape-speed, servo control system.

› A unique vacuum tension/cleaning pad located immediately in front of the recording or reproducing head provides gentle, but firm and precise, tape tension. The head in turn is mounted almost in contact with the drive capstan. This arrangement results in a very short span of tape that requires controlled positioning. The combination of these features results in minimum skew, less flutter, and fewer dropouts.

For the name of the technically qualified Sangamo Representative nearest you, and for complete details on the Sangamo 460-Series system, please write for Bulletin 3400.

SANGAMO 460-SERIES PERFORMANCE and CHARACTERISTICS

Start Time: 1.0 second to synchronism @ 60 ips with servo speed control and 1″ wide tape.

Stop Time: 0.2 seconds from 60 ips.

Instantaneous Time Displacement Error: Less than 25.0 microseconds (including flutter) @ 60 ips.

Long Term Time Displacement Error: ±0.01% standard. Higher accuracies available.

Interchannel Time Displacement Error: ±2.0 microseconds @ 60 ips between outside tracks on 1″ tape.

Servo Speed Control Range: ±15% nominal tape speed.

Servo Speed Control Response: ±15% speed change per second.

Tape Widths: Standard sizes from ¼ to 2″.

Reel Sizes: 14″ or smaller.

Mounting: 1 standard 19″ equipment rack for a complete 14 track record/reproduce system with power supplies and servo speed control.

Power Requirements: 117 volts, 60 cps ±10% single phase. All D C drives. 7.0 amperes load for 14 track system.

Weight: Approximately 500 pounds for 14 track system.

SANGAMO ELECTRIC COMPANY

SPRINGFIELD, ILLINOIS

ES61-3

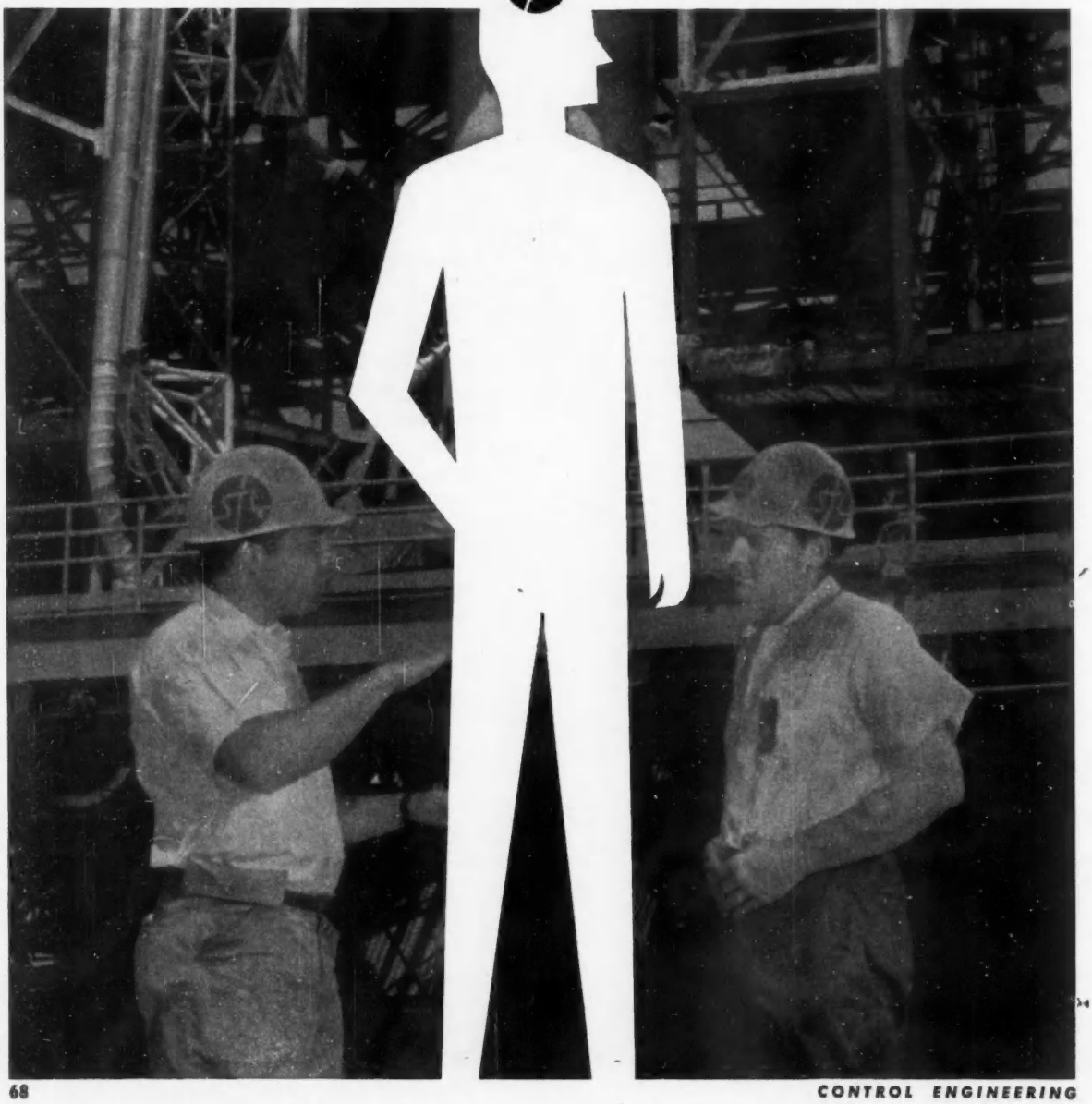
A special breed of generalist for **S**pace **T**echnology **L**eadership

America's dramatic accomplishments in space technology are made possible not only by developments in science, but by advances in technical management concepts. A new type of generalist has emerged to meet the demands of systems engineering and technical direction of complex missile and space projects. This technical manager combines a broad knowledge of science and engineering with the leadership capability to fuse the disciplines of creative specialists into a dynamic, effective team ● In its six years as a principal contractor for the Air Force, NASA, and ARPA, STL's hard core of technical management generalists has set the pace in developing new members of this very scarce breed ● Their unique ability is the prime asset in Space Technology Leadership ● Scientists and engineers who would add this new management dimension to their professional careers are invited to submit their resumes to STL, where they will receive meticulous attention.

SPACE TECHNOLOGY LABORATORIES, INC. P.O. BOX 95005 PQ, LOS ANGELES 45, CALIFORNIA

a subsidiary of Thompson Ramo Wooldridge Inc.

El Segundo • Santa Maria • Edwards Rocket Base • Canoga Park — Cape Canaveral • Manchester, England • Singapore • Hawaii



A three year test proves that our ultra long life **NIXIE®** tubes have 100* times longer life than any other electronic readout.

Consider this, then add the factors of lowest cost, smallest size, lightest weight, lowest power, most readable, and we feel you will agree **NIXIE** tubes are, beyond the shadow of a doubt, the finest in-line readouts ever made.

*Life tests prove 20,000 hours life on one number without a single failure. In a decimal readout, this represents a minimum life of 200,000 hours. Since no failures have occurred to date, the figures quoted are minimums. Write for the Readout Fact Finder, an engineering comparison of all readout devices.

ANOTHER ELECTRONIC CONTRIBUTION BY

Burroughs Corporation

ELECTRONIC COMPONENTS DIVISION

PLAINFIELD, NEW JERSEY

Formerly Electronic Tube Division

CIRCLE 69 ON READER SERVICE CARD

New

LAMBDA Transistorized REGULATED POWER SUPPLIES

0 - 34 VDC 5, 10 and 20 Amp
20 - 105 VDC 2, 4 and 8 Amp
75 - 330 VDC 0.8, 1.5 and 3 Amp

CONVECTION COOLED
No Blowers or Filters
Maintenance Free

Highly efficient, radiator type heat sinks eliminate internal blowers, maintenance problems, risk of failure, moving parts, noise and magnetic fields. Units are rated for continuous duty at 50°C ambient.

SHORT CIRCUIT PROOF

All models are completely protected with magnetic circuit breakers, fuses, and thermal overload.

EASY SERVICE ACCESS

Dual-deck, swing-out back construction provides simple and fast service access without the need to remove unit from rack. All major component terminals are accessible from rear.

REMOTE SENSING

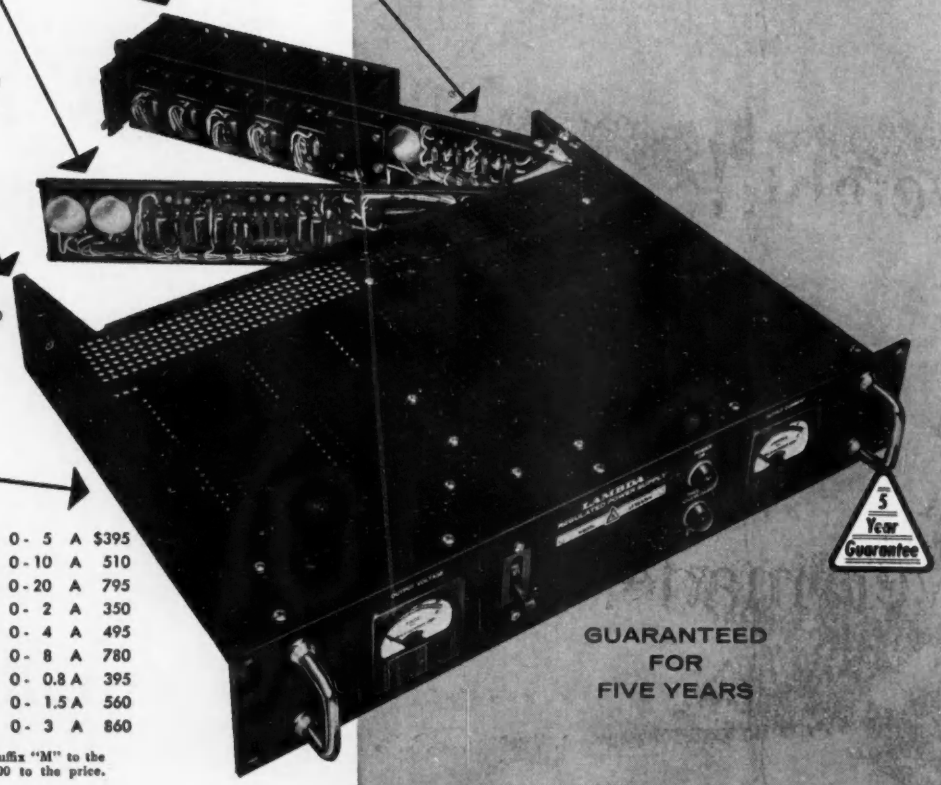
Minimizes effect of power output leads on DC regulation, output impedance and transient response.

NO VOLTAGE SPIKES OR OVERSHOOT

Lambda's design prevents output voltage overshoot on "turn on, turn off," or power failure.

MIL QUALITY

Hermetically-sealed magnetic shielded transformer designed to MIL-T-27A quality and performance. Special, high-purity foil, hermetically-sealed long life electrolytic capacitors.



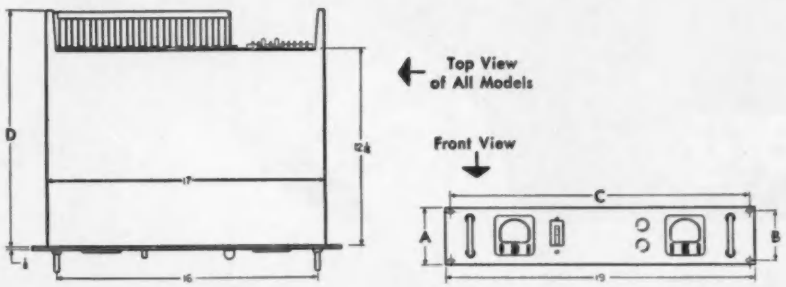
LA 50 - 03A	0 - 34 VDC	0 - 5	A	$395
LA100 - 03A	0 - 34 VDC	0 - 10	A	510
LA200 - 03A	0 - 34 VDC	0 - 20	A	795
LA 20 - 05A	20 - 105 VDC	0 - 2	A	350
LA 40 - 05A	20 - 105 VDC	0 - 4	A	495
LA 80 - 05A	20 - 105 VDC	0 - 8	A	780
LA 8 - 08A	75 - 330 VDC	0 - 0.8	A	395
LA 15 - 08A	75 - 330 VDC	0 - 1.5	A	560
LA 30 - 08A	75 - 330 VDC	0 - 3	A	860

For metered models add the suffix "M" to the model number and add $30.00 to the price.

GUARANTEED FOR FIVE YEARS

LA-117

DIMENSION DRAWINGS



MODEL †			
	LA 50-03A LA 20-05A LA 8-08A	LA 100-03A LA 40-05A LA 15-08A	LA 200-03A LA 80-05A LA 30-08A
A	3½"	7"	10½"
B	3"	*4"	*7½"
C	18⅝"	18¼"	18¼"
D	14⅜"	14⅜"	16½"

* These models notched per RETMA Standards
† Includes metered models with suffix "M"

COMPLETE SPECIFICATIONS OF LAMBDA LA SERIES

DC OUTPUT (Regulated for line and load)

Model	Voltage Range (1)	Current Range	Minimum Voltage (1)	Voltage Steps (1)	Price (2)
LA 50-03A	0- 34 VDC	0- 5 AMP	0	2, 4, 8, 16, and 0- 4 volt vernier	$ 395
LA100-03A	0- 34 VDC	0-10 AMP	0	2, 4, 8, 16, and 0- 4 volt vernier	510
LA200-03A	0- 34 VDC	0-20 AMP	0	2, 4, 8, 16, and 0- 4 volt vernier	795
LA 20-05A	20-105 VDC	0- 2 AMP	20	5, 10, 20, 40, and 0-10 volt vernier	350
LA 40-05A	20-105 VDC	0- 4 AMP	20	5, 10, 20, 40, and 0-10 volt vernier	495
LA 80-05A	20-105 VDC	0- 8 AMP	20	5, 10, 20, 40, and 0-10 volt vernier	780
LA 8-08A	75-330 VDC	0- 0.8 AMP	75	15, 30, 60, 120, and 0-30 volt vernier	395
LA 15-08A	75-330 VDC	0- 1.5 AMP	75	15, 30, 60, 120, and 0-30 volt vernier	560
LA 30-08A	75-330 VDC	0- 3 AMP	75	15, 30, 60, 120, and 0-30 volt vernier	860

(1) The DC output voltage for each model is completely covered by four selector switches plus vernier control. The DC output voltage is the summation of the minimum voltage plus the voltage steps and the continuously variable DC vernier.

(2) Prices are for unmetered models. For metered models add the suffix "M" and add $30.00 to the price.

Regulation (line) ..... Less than 0.05 per cent or 8 millivolts (whichever is greater). For input variations from 100-130 VAC.

Regulation (load) ..... Less than 0.10 per cent or 15 millivolts (whichever is greater). For load variations from 0 to full load.

Transient Response ..... Output voltage is constant within regulation specifications for step function:

(line) ..... line voltage change from 100-130 VAC or 130-100 VAC.

(load) ..... load change from 0 to full load or full load to 0 within 50 microseconds after application.

Internal Impedance .... LA 50-03A less than .008 ohms
LA100-03A less than .004 ohms
LA200-03A less than .002 ohms
LA 20-05A less than .06 ohms
LA 40-05A less than .03 ohms
LA 80-05A less than .015 ohms
LA 8-08A less than .5 ohms
LA 15-08A less than .25 ohms
LA 30-08A less than .15 ohms

Ripple and Noise ..... Less than 1 millivolt rms with either terminal grounded.

Polarity ..... Either positive or negative terminal may be grounded.

Temperature Coefficient ..... Less than 0.025 %/°C

AC INPUT ..... 100-130 VAC, 60 ± 0.3 cycle[3]
LA 50-03A....360 watts[4]
LA100-03A....680 watts[4]
LA200-03A...1225 watts[4]
LA 20-05A....390 watts[4]
LA 40-05A....710 watts[4]
LA 80-05A...1350 watts[4]
LA 8-08A....415 watts[4]
LA 15-08A....760 watts[4]
LA 30-08A...1450 watts[4]

[3]This frequency band amply covers standard commercial power lines in the United States and Canada.
[4]With output loaded to full rating and input at 130 VAC.

AMBIENT TEMPERATURE AND DUTY CYCLE Continuous duty at full load up to 50°C (122°F) ambient.

OVERLOAD PROTECTION:

Electrical ..... Magnetic circuit breaker front panel mounted. Special transistor circuitry provides independent protection against transistor complement overload. Fuses provide internal failure protection. Unit cannot be injured by short circuit or overload.

Thermal ..... Thermostat, manual reset, rear of chassis. Thermal overload indicator light front panel.

METERS ..... Voltmeter and ammeter on metered models.

CONTROLS:

DC Output Controls ... Voltage selector switches and adjustable vernier-control rear of chassis.

Power ..... Magnetic circuit breaker, front panel.

Remote DC Vernier .... Provision for remote operation of DC vernier.

Remote Sensing ..... Provision is made for remote sensing to minimize effect of power output leads on DC regulation, output impedance and transient response.

PHYSICAL DATA:

Mounting ..... Standard 19" Rack Mounting

Size

LA 50-03A, LA20-05A, LA 8-08A 3½" H x 19" W x 14⅜"D
LA100-03A, LA40-05A, LA15-08A 7" H x 19" W x 14⅜"D
LA200-03A, LA80-05A, LA30-08A 10½" H x 19" W x 16½"D

Weight

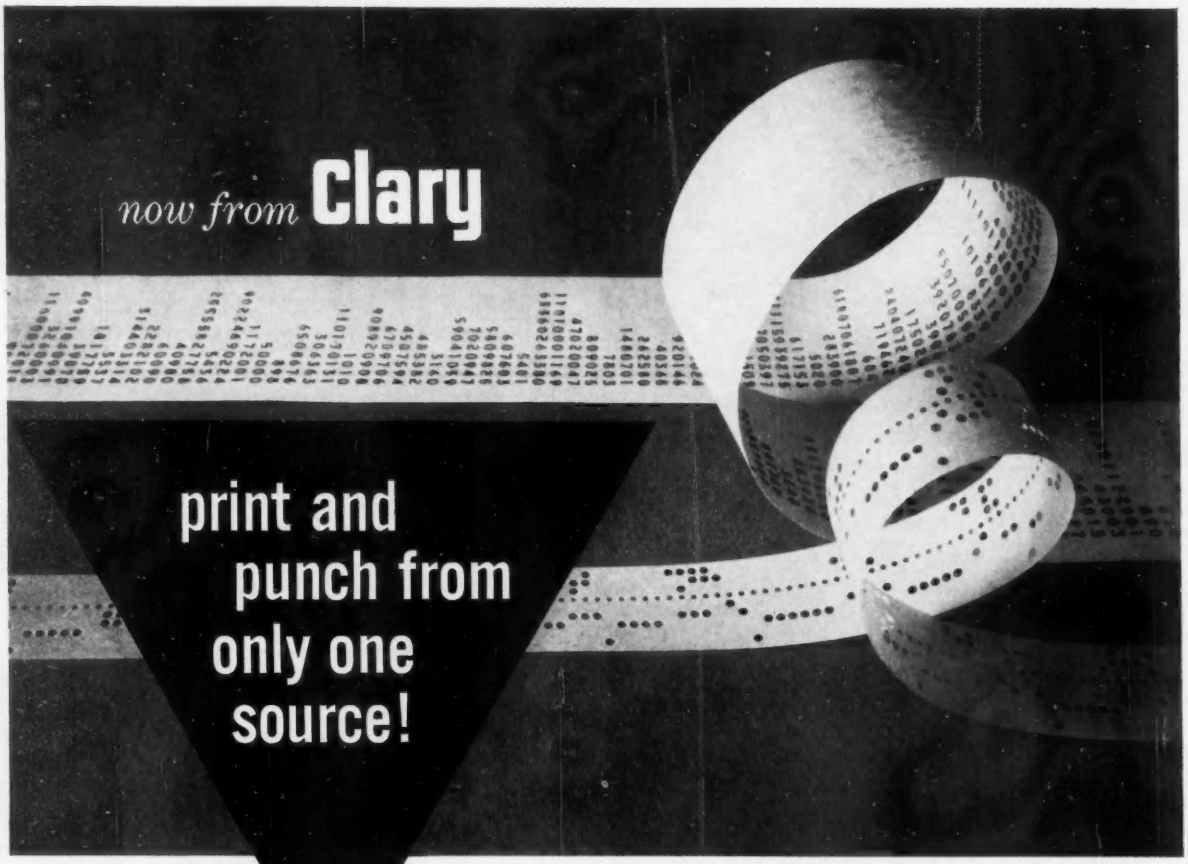
LA 50-03A, LA20-05A, LA 8-08A 55 lb Net 85 lb Ship. Wt.
LA100-03A, LA40-05A, LA15-08A 100 lb Net 130 lb Ship. Wt.
LA200-03A, LA80-05A, LA30-08A 140 lb Net 170 lb Ship. Wt.

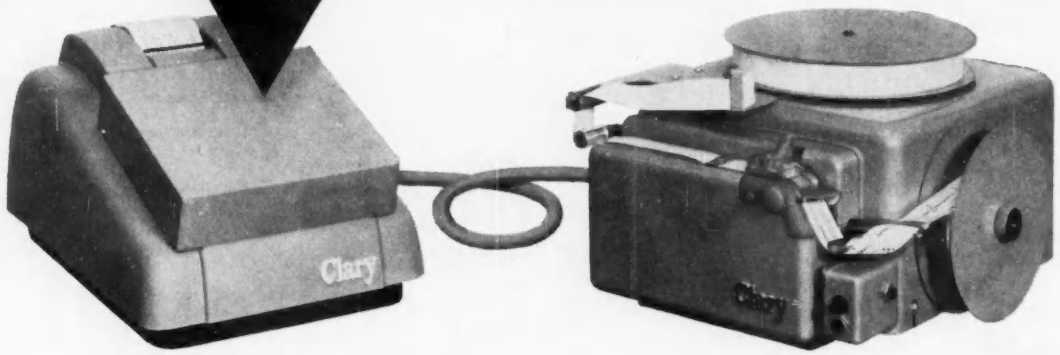
Panel Finish ..... Black ripple enamel (standard). Special finishes available to customers' specifications at moderate surcharge. Quotation upon request.

LAMBDA ELECTRONICS CORP.
515 BROAD HOLLOW ROAD, HUNTINGTON, L. I., NEW YORK 516 MYRTLE 4-4200

CIRCLE 71 ON READER SERVICE CARD

Send for complete Lambda Catalog.





Now, with just *one* output from the data source, you can record information in reusable form *two* different ways – on printed tape, and on punched tape.

The secret of this simpler, faster, more economical recording method is Clary's special printer-perforator combination. This versatile unit prints out information from a wide range of data sources and records it on a "common language" punched tape.

The taped data can be kept for permanent records... mailed or directly teletyped to distant points... used as language for computers, process control units, and in other industrial applications.

For further information on this unit, or for help with any data-handling problem, just phone or write Clary.

Specification notes:

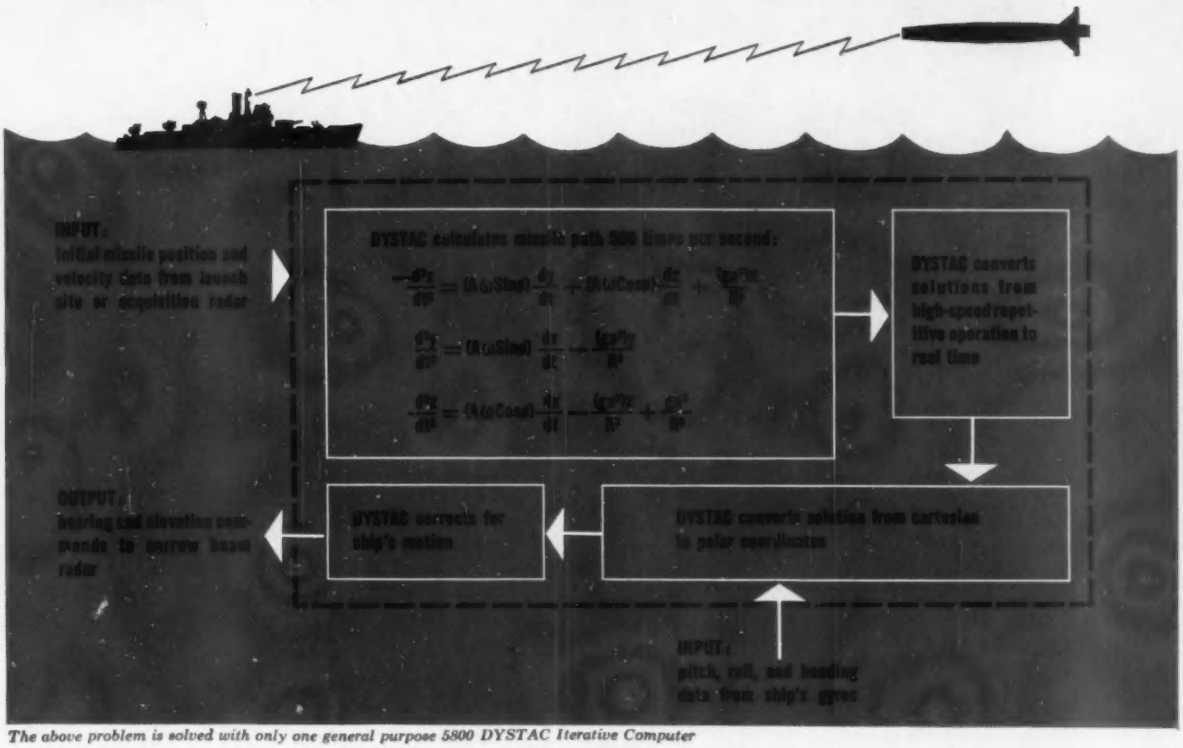
The printer used may be serial or parallel entry. The tape perforator will punch any number up to 8 transversely-spaced code hole channels, and the format is programmable.

Clary ELECTRONICS
San Gabriel, California

In Canada: Computing Devices of Canada, Ltd., Ottawa

only one analog computer can do it:

5800 DYSTAC® Iterative Analog Computer Keeps Shipboard Radar Locked on Missile



The above problem is solved with only one general purpose 5800 DYSTAC Iterative Computer

Dynamic memory and high-speed repetitive calculations in DYSTAC provide drift-free solutions to problems over real time periods of almost any length! The missile in this problem may be in range for many minutes... but DYSTAC-directed radar stays locked-on, despite the passing of time, and the various motions of missile and ship.

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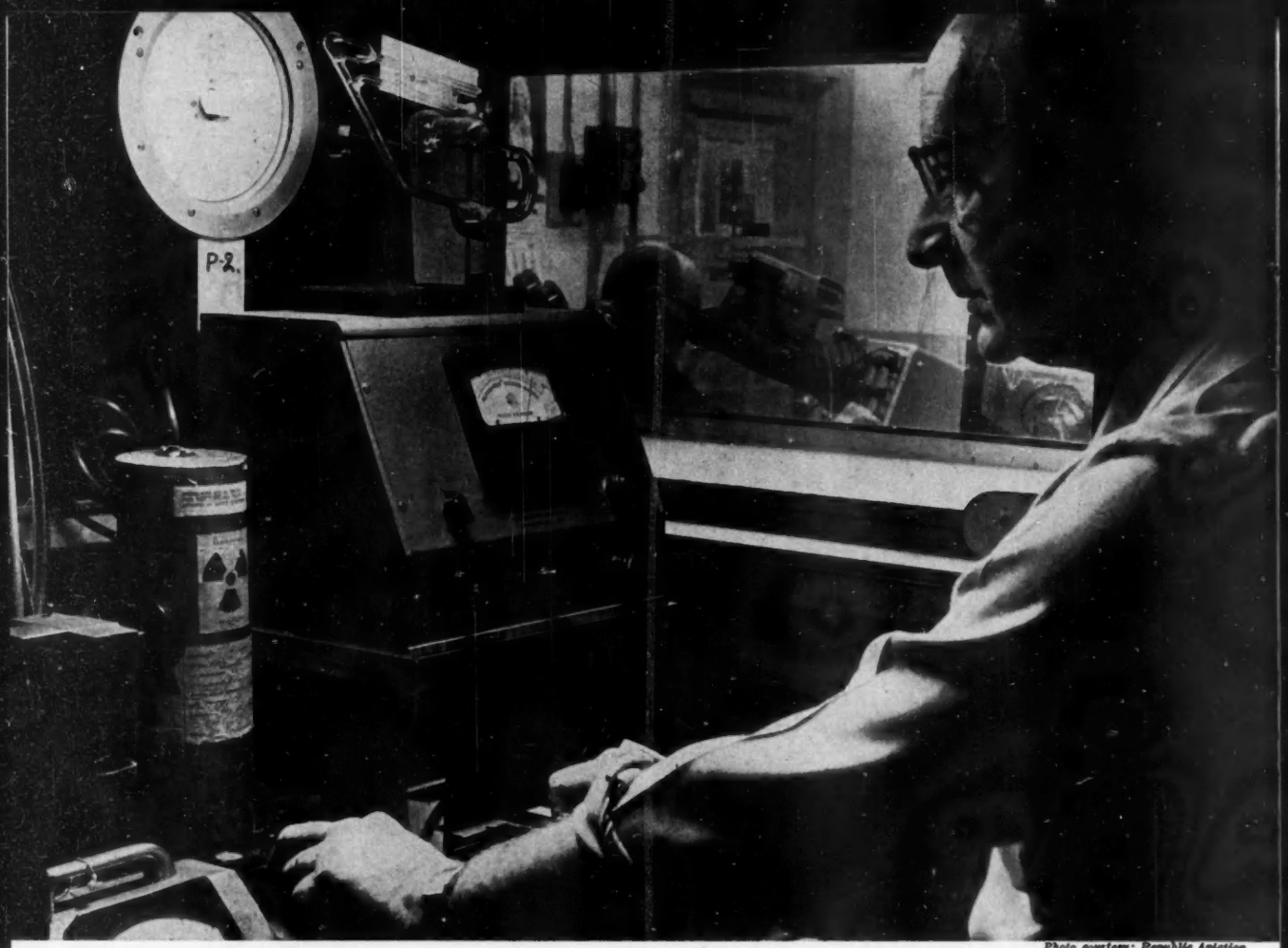

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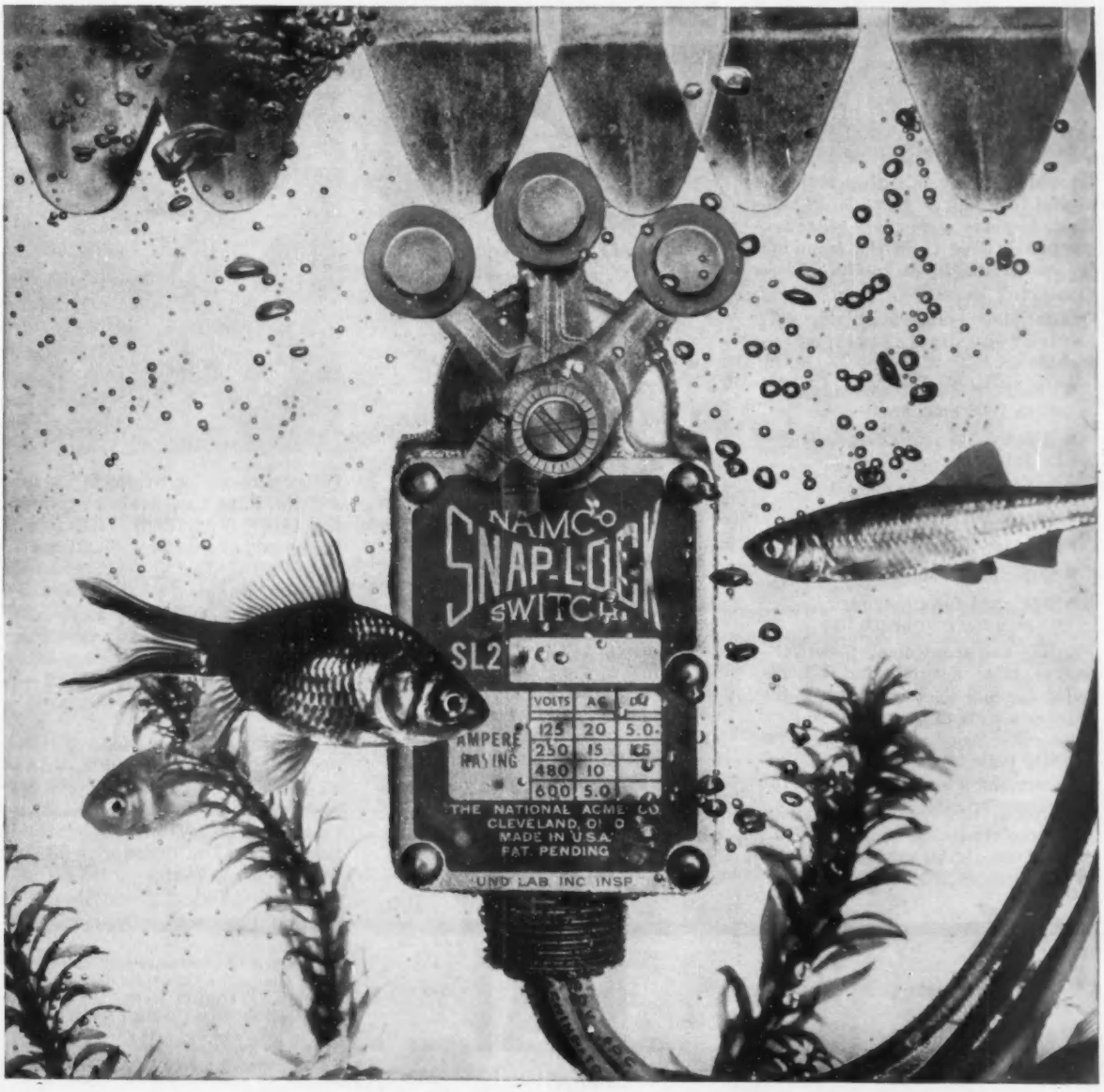

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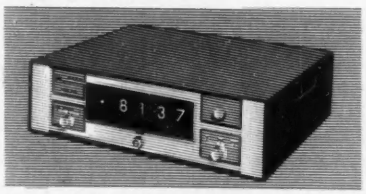

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- 200 readings per second
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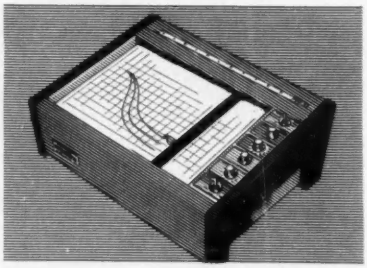

Features of special interest include:

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- Pen acceleration of 750 inches /sec.^{2}
- Slewing speed—20 inches/sec.
- High input impedance up to 1 megohm/volt
- 11 x 17 inch plotting area
- Compact, rugged construction
- Accepts differential inputs
- Available with continuously variable scale factor

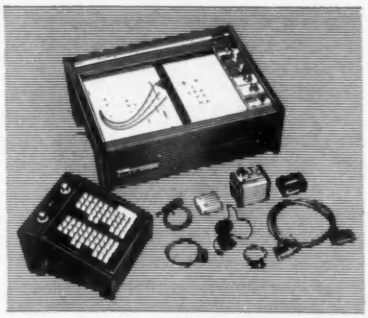
In addition, a full line of accessories makes the EAI Model 1100E VARIPLOTTER a fully flexible engineering tool . . . timebase generators . . . function generators . . . symbol printers . . . digital input keyboards.

Write to Department 18 for complete details on how the Model 1100E VARIPLOTTER can save you costly engineering time.

HOW TO GET MORE OUT OF YOUR VARIPLOTTER

EAI Series 1100E VARIPLOTTER is an effective and accurate 11-x-17 X-Y Plotter. However, with the addition of one or more of the available accessories, its usefulness and performance are greatly increased.

For example, Keyboard Accessory Series 1150 is a manual input device that enables the 1100E VARIPLOTTER to be used for accurate and rapid graphical plotting of digital information. The three digit keyboard has been designed to speed and simplify manual data input. As a result, you can get faster, more accurate, and more reliable recording of digital data.



Other accessories available include a Time Base Generator to convert the 1100E VARIPLOTTER into a time base recorder; a semi-automatic Symbol Printer Accessory which permits graphical plotting with up to six different identifying symbols; a Function Generator to convert the 1100E into a high accuracy curve following device; and BIVAR—a bi-variant function generator.

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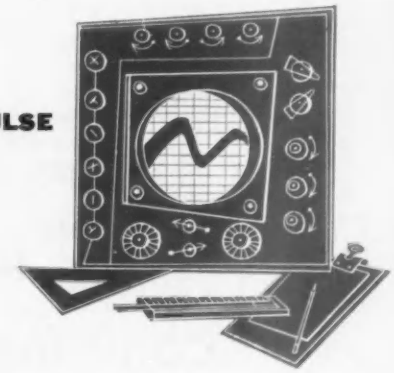

Computer Logger Report

The most frequent application of process control computers is still in open-loop operation, where the machine performs as a data logger, a monitor, or an operating guide calculator. The accumulation of data remains a key function in chemical and petroleum processing plants, steel mills, and electric utility stations, so much so that many users can justify a computer for this purpose on grounds of economy.

A computer offers a user a number of advantages compared with a pure logger. First, he can obtain refined data upon which considerable calculation has been performed instead of the raw information of production. Then too, the computer can perform some logic and decision-making if needed. And finally, the user has one leg up on a closed-loop computing-control application. Experience gained with the computer as a logger is valuable if the company wants to go all the way with closed-loop computing control. Most closed-loop computer control installations start this way.

To indicate the breadth of application of process control computers for this function, CONTROL ENGINEERING surveyed computer makers to compile a census of applications. Some unexpected bits of information turned up. For example, IBM has not yet sold its first 1710 machine, the first computer intended for process control. Also, Litton Industries has forsaken the process control computer field. The company's only project —at Sun Oil in Philadelphia—was cancelled, and the company has had trouble getting additional orders in the processing field.

The census:

UTILITY INDUSTRY

DATE ON LINE	USER AND LOCATION	COMPUTER	FUNCTIONS
1958	Louisiana Power and Light Co. Sterlington Station	Daystrom	Calculating over-all station efficiency
1959	Public Service of Colorado Denver	Libratrol 500	Calculating natural gas distribution
1960	Carolina Power and Light Co. H. B. Robinson Station	Daystrom	Calculating boiler and turbine efficiency
1960	Gulf States Utilities Willow Glenn Station	Daystrom	Calculating boiler and turbine efficiency
1960	Public Service Electric and Gas Bergen Station	LN 3000	Calculating operating guides
1960	Electricite de France (Unit No. 1) Chinon, France	RW-300	Radiation monitoring and logging
1961	Electricite de France (Unit No. 2) Chinon, France	RW-300	Radiation monitoring and logging

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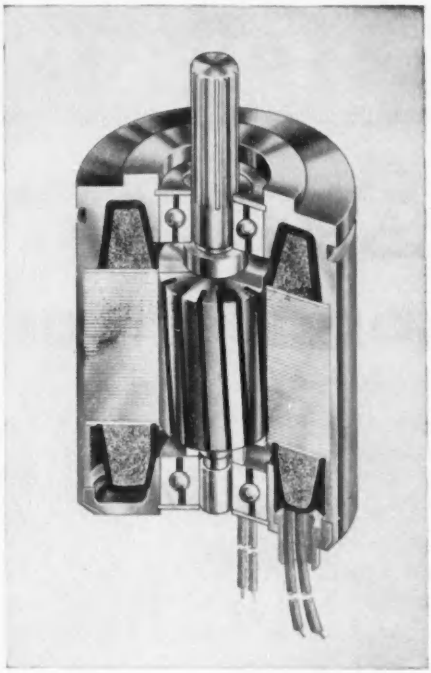

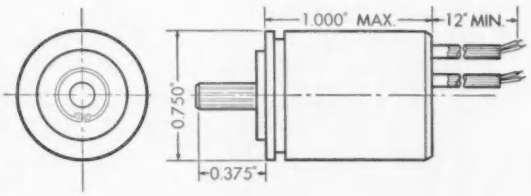

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- Efficient operation over the ambient temperature range of—55°C to +125°C.
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TYPICAL PERFORMANCE CHARACTERISTICS			
Type Number	008E2A	008E2C	008E2D
Excitation Frequency (cps)	400	400	400
Rated Voltage:			
Fixed phase (volts)	26	26	26
Control phase (volts)	26	40/20	26
Input Power at Stall (watts)	1.75	1.75	2.50
Starting Voltage (volts)	0.68	1.0	0.68
Stall Torque (oz. -in.)	0.22	0.22	0.30
Ratio Stall Torque to Total Power Input	0.060	0.060	0.060
Rotor Inertia (gm. cm^2)	.414	.414	.414
Acceleration at Stall (rad./$sec.^2$)	36,000	36,000	53,000
No Load Speed (rpm)	6,500	6,500	6,500
Temperature Rise at Stall (°C)	50	50	60
Operating Temperature Range (°C)	−55 to +125	−55 to +125	−55 to +125

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NORDEN DIVISION
KETAY DEPARTMENT, COMMACK, LONG ISLAND, NEW YORK

DATE ON LINE	USER AND LOCATION	COMPUTER	FUNCTIONS
1961	Tennessee Valley Authority Colbert Steam Plant	RW-300	Monitoring and logging
1961	Duquesne Power and Light Shippingport Atomic Power Station	Daystrom	Calculating calorimetric values and heat balances
1961	Kansas Gas and Electricity Gordon Evans Station	Daystrom	Calculating boiler and turbine efficiency
1961	Bethlehem Steel Buffalo, N. Y.	GE 312	Logging and monitoring power plant
1961	Puerto Rican Water Authority Palo Seco, P. R.	GE 312	Monitoring and logging
1961	Public Service of Oklahoma Northeast Station	GE 312	Monitoring and logging
1961	South Carolina Electric & Gas Co. Columbia, S. C.	GE 312	Economic dispatching
1961	South Carolina Electric & Gas Co. Columbia, S. C.	GE 312	Logging and monitoring
1961	Gulf States Utilities Co. Lake Charles, La.	ISI 609	Monitoring and logging
1961	Boston Edison Mystic Station	ISI 609	Monitoring steam and electric equipment
1961	Northern Illinois Gas Chicago	ISI 609	Monitoring gas transmission
1961	Philadelphia Electric Co. Conowingo, Md.	D-290	Economic dispatch
1962	Arizona Public Service Co. Cholla Station	GE 412	Logging and monitoring

CHEMICAL AND PETROLEUM

DATE ON LINE	USER AND LOCATION	COMPUTER	FUNCTIONS
1959	Riverside Cement Co. Oro Grande, Calif.	RW-300	Logging kiln data; calculating blending; guiding quarry operation
1959	Standard Oil of N.J. Baton Rouge	LGP-30	Calculating operating guides
1959	Standard of California Richmond, Calif.	Recomp II	Computing optimum product run
1960	duPont Beaumont, Texas	ISI 609 (2)	Logging
1960	Owens-Corning Fibreglas Aiken, S.C.	ISI 609	Scanning and comparing operating guides
1961	Shell Chemical Co. Portable unit	PB 250	Logging, monitoring, and computation
1961	Aurora Gasoline Co. Detroit, Mich.	Recomp II	Calculating optimum blending mix
1961	Kaiser Steel Fontana, Calif.	GE 312	Logging on a tin line

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TYPE NO.	APPLICATION	MILITARY SPEC. NO.
2N128	High frequency amplifier	MIL-T-19500/9A
2N240	High speed switch	MIL-S-19500/25A
2N393	High speed switch	MIL-S-19500/77A (Sig C)
2N495	Medium frequency amplifier (Silicon)	MIL-T-19500/54A (Sig C)
2N496	Medium speed switch (Silicon)	MIL-S-19500/85 (Sig C)
2N499	VHF amplifier	MIL-S-19500/72A (Sig C)
2N501A	Very high speed switch	MIL-T-19500/62 (Sig C)
2N502A	VHF amplifier	MIL-S-19500/112 (Sig C)
2N599	Medium speed switch	MIL-S-19500/166 (Navy)
2N1118	Medium frequency amplifier (Silicon)	MIL-S-19500/138 (Sig C)
2N1119	Medium speed switch (Silicon)	MIL-S-19500/139 (Sig C)
2N1158A	VHF oscillator	MIL-S-19500/113 (Sig C)
2N1199A	High speed switch	MIL-S-19500/131 (Sig C)
2N1200	HF amplifier (Silicon)	MIL-S-19500/105 (Sig C)
2N1201	HF amplifier (Silicon)	MIL-S-19500/101 (Sig C)
2N1411	High speed switch	MIL-S-19500/133 (Sig C)
2N1499A	High speed switch	MIL-S-19500/170 (Sig C)
2N1500	Very high speed switch	MIL-S-19500/125 (Sig C)

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MAY 1961

"Automation"— The Whipping Boy

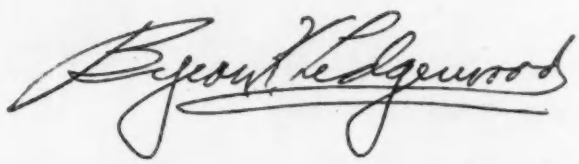
A lot of people wish the word "automation" had never been coined, since its ill-defined status makes it a convenient crutch on which to blame the troubles of the world. To the layman it is a giant brain, conjuring up visions of operatorless factories run by robots. To the old lathe hand it is the limit switch they added to his machine. To the process operator it is a computer running a refinery. To the clerk it is a data processor preparing payroll checks. And to many, many people it is anything that increases productivity.

The labor movement in particular has seized on automation as the main whipping boy when unemployment rises or when the work force is reduced because of increased productivity. Automation is putting small cargo in a large container, for example, to reduce loading time and manpower requirements while cutting pilferage. While in another case automation is buying a new machine with three times the spindle horsepower, a more rigid frame, better cutting tools, and four times the productive capacity. Technological improvements, whether they result from improved processes or addition of controls, are being credited to (or blamed on, depending on how you look at it) automation.

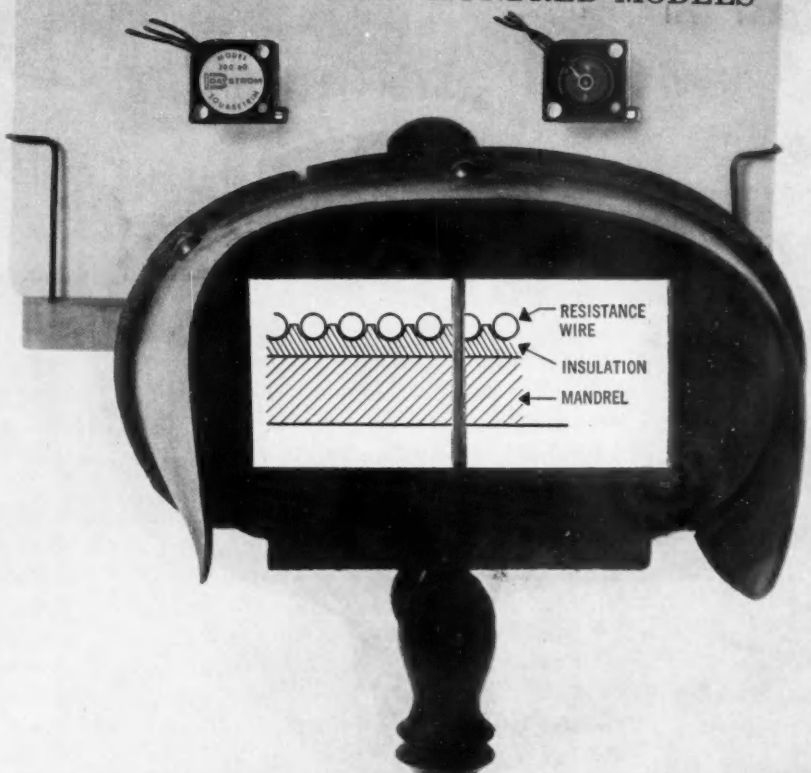
In actuality, part of productivity improvement can usually be attributed to increased production equipment capabilities and part to the addition of controls. How many times have you heard of the situation where a systems analysis performed during the development of a complex control system ended up showing that changes in the basic process could improve productivity to the extent that the controls could no longer be economically justified? This would undoubtedly be called an "automated" process, even though it is no more automatic at the end than at the beginning; it just runs more efficiently.

What we must recognize is that the fuzzy meaning and layman-aura surrounding automation make it an ideal catchword for people who are actually resisting the general technological improvement of production processes. It would be difficult to raise a furor by telling how better materials, improved processes, and automatic controls have raised productivity, but blame it all on automation, then people sit up and take notice.

Certainly we must face up to our responsibilities with regards to technological unemployment. But as control engineers we should make it our job to clearly distinguish between the increased efficiencies gained through the intelligent application of automatic systems and the gross gains now being attributed to something called automation. Automation just isn't that good.



SECRETS OF FIFTEEN HUNDRED MODELS



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HYDRAULIC LOGIC: *What's Its Potential?*

Signal-level hydraulic switching devices offer a new tool from which to build logic networks. Speed is about the same as that of conventional relays, while a simple valve's logic power lies midway between that of transistors and relays. Although hydrodynamic and inertial effects cause problems, practical devices have been built and more are proposed. And the future looks bright since the use of plastic molding techniques to form multielement units promises lower production costs and higher switching speeds.

H. H. GLAETTLI
Zurich Research Laboratory
International Business Machines Corp.

Conventional on-off hydraulic valves that control the flow of fluid to power cylinders are actually logic devices, although they are usually not thought of as such. But by shrinking the same general configurations until they become signal-level devices rather than power controllers, and by combining them in suitable circuits, hydraulic logic networks such as shift registers and matrices can be created that previously have been constructed only from electrical or electronic components. Information is represented by the presence of one of two pressure levels or by the position of valves and pistons. Although multiposition devices are possible, this investigation has been limited to binary arrangements because of speed advantages and ease of manufacture.

The simplest logic building block is shown in Figure 1. Here P_m is an intermediate pressure (between a high pressure P_h and a low pressure P_l); A, M, and N are input terminals; and X is the output terminal. Applying a binary signal, having the values P_h or P_l, to each of the input terminals turns this device into a logic element whose operation can be described by this Boolean expression:

$$X = MA' + NA$$

This logic operation cannot be achieved with a single transistor, but it is possible on a relay with a single transfer contact.

The second basic device is the bistable element of Figure 2, formed by back coupling output terminal X of Figure 1 to input terminal A. Under normal conditions a low pressure signal P_l is maintained at port M and a high pressure signal P_h at port N. Applying a momentary P_h pulse to port M when the valve is in the lower position (as shown) causes it to switch to the upper position and remain there. The switch back to the lower stable position occurs when a P_l pulse is applied at port N.

Any number of variations of these two basic elements is possible. For example, a valve with unequal driving areas and a relief section forms a four-input/one-output device. But even though single element units can possess high logic power, they are of little use until they are interconnected to form logic networks. Five typical hydraulic logic networks are shown and described in Figure 3,

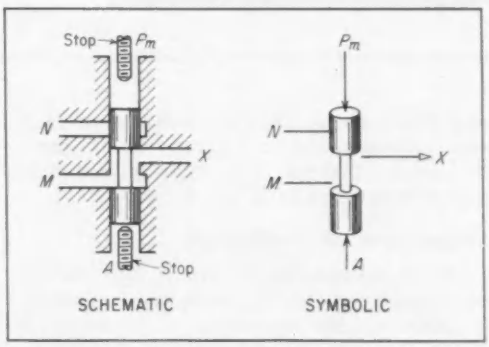


FIG. 1. Simplest logic building block.

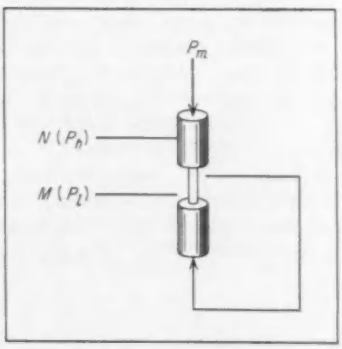
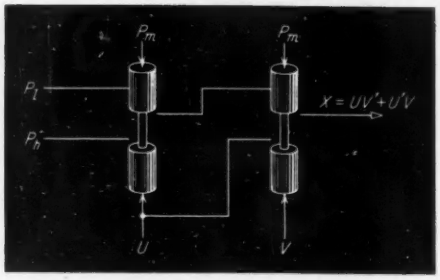


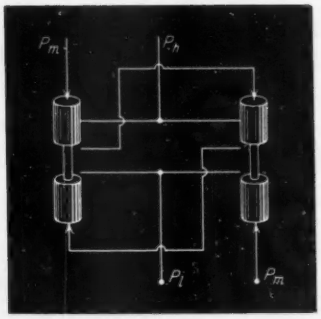
FIG. 2. Bistable element.

FIG. 3 ELEMENTS COMBINED TO FORM LOGIC CIRCUITS



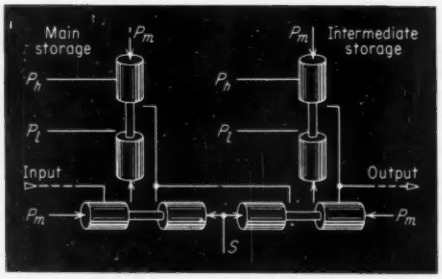
A—Exclusive OR Circuit

This circuit can be derived by cascading two of the basic elements shown in Figure 1. In words, the Boolean expression states that there will be a P_h output at X if P_l is applied at U and P_h at V OR if P_h is applied at U and P_l at V. The same input at both U and V, regardless of whether it is P_h or P_l, will yield a P_l output at X. No other elements (passive or active) are required to form a practical circuit. But complete isolation no longer exists between input and output because the U input feeds both elements.



B—Multivibrator

Simple multivibrator (similar to a relaxation oscillator) uses three pressure levels and only one switching action per valve. In position shown the right-hand valve is about to move up, after which the left-hand valve will move up, the right down, etc. Oscillation frequency depends on element size, fluid characteristics, and pressure.



C—Shift Register

The complete unit cell shown here will handle one bit and is connected to identical preceding and succeeding cells to form a working register. A binary pressure pulse train (P_l or P_h) is applied at S. With P_h at S the main storage valve is positioned by the input binary signal from the preceding valve, while the intermediate valve supplies a remembered binary output to the succeeding cell. With P_l at S the signal just stored in the main valve is shifted internally to the intermediate valve. Thus a binary signal is taken in, shifted across, and out of the cell.

ranging from a simple exclusive OR circuit to a reasonably complex matrix. Extensions of these can be visualized that may someday form complete hydraulic arithmetic units.

The uniqueness of hydraulics

The simple calculations shown in the box on page 86 demonstrate that hydraulic logic elements can be made roughly equivalent to conventional relays in operating speed and power requirements. But a closer look at the special problems encountered in constructing, interconnecting, and testing hydraulic networks shows several basic differences between them and analogous electrical circuits.

- Potential energy storage in hydraulic circuits is difficult since the fluid's physical characteristics—volume, noncompressibility—do not encourage the use of pressure vessels. Compare this with capacitor storage in electrical systems.
- Response of hydraulic units depends directly on fluid inertia, corresponding to the electrical self-inductance phenomena. Hydraulic channels must be kept short for fast response (see box, page 86).
- Transmission propagation velocity of hydraulic systems is low considering element size and response time: velocity of sound for hydraulics compares with velocity of light for electricity.
- Measurements on the units are tricky because they require mechanical modifications which in turn introduce new disturbances. Besides, little suitable hydraulic measuring equipment is available.
- Although some of the transient effects in hydraulic circuits have electrical equivalents—sudden cessation of flow produces pressure peaks comparable to inductive surges—cavitation and other fluid flow phenomena have no direct analogies.

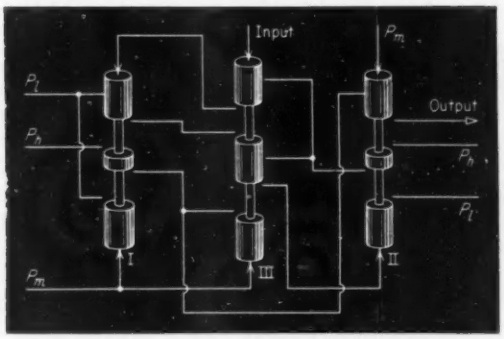
The limitation on operating speed is not the only effect of fluid inertia and low fluid propagation velocities. The difficulties introduced when coupling several units together are as important. In practice, only slight differences in channel length may cause malfunctioning of a shift register controlled from a central pulse generator (Figure 3C). Circuit layout is also complicated by the need for strict control of channel length. Here the topological problems resemble those encountered in the

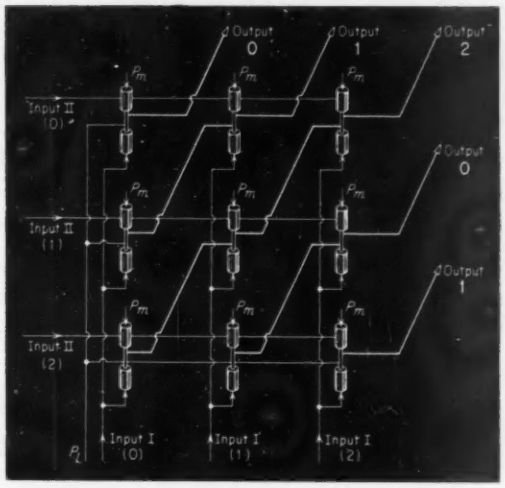
D—Scale-of-Two Counter

This is a special case of a hydraulic shift register. The central valve acts as a buffer amplifier while the other two are comparable to triodes in an electronic flip-flop. The table shows a complete cycle including the input and output binary pressure signals and the positions of the three valves: *U* for up and *D* for down:

Input	*III*	*I*	*II*	*Output*
P_h	*D*	*D*	*D*	P_h
P_l	*U*	*U*	*D*	P_h
P_h	*D*	*U*	*U*	P_h
P_l	*U*	*D*	*U*	P_l

Every two complete cycles of the input signal yields one complete cycle of the output signal, thus the scale-of-two counting action. The pressure signals in the output channel indicate that a pulse-shaping action takes place so that several stages can be cascaded without differentiating elements. A multistage binary counter can be formed in this manner.





E—Hydraulic Matrix

The most powerful application of hydraulic logic elements may be in the form of matrices. The three-by-three matrix shown here uses nine AND gates based on the element shown in Figure 1. Nine outputs are possible if this circuit is employed as a selection matrix, but as connected here with five outputs the matrix serves as a two-input adder in the one-out-of-three code. The look-up table is:

Inputs	*II(0)*	*II(1)*	*II(2)*
I(0)	*0*	*1*	*2*
I(1)	*1*	*2*	*0*
I(2)	*2*	*0*	*1*

A binary signal (P_h) at one of the three II inputs and another at one of the three I inputs yields a 0, 1, or 2 output as indicated by the table and by tracing through the diagram. Thus the output is the sum of the two inputs and is still in the one-out-of-three code. Two of the outputs are redundant and the matrix could be wrapped around to leave three unique output channels.

design of printed circuit boards, but are complicated by the third dimension.

Feedback over common coupling lines often causes difficulty when several elements are connected to a common high pressure line. No theory has been derived that can predict these effects, and proper functioning of a large group of units comes only from careful experimentation.

The effect of size

Probably the most important questions are how small can these units be and how does this affect speed. Although exact answers require detailed study of each design, certain general rules apply. As the lineal dimension of a unit decreases, valve displacement diminishes in the same ratio. This simultaneously reduces channel length and inertia, but offsetting this is an increase in viscous losses. This is shown in Figure 4 for constant pressure and tolerances proportional to the lineal dimension.

Here miniaturization not only decreases the volume by a factor $(l/l_o)^3$ but it reduces the response time as well. At low viscosities this response

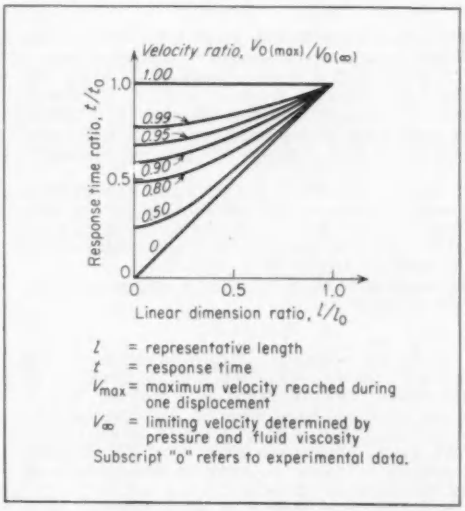


FIG. 4. Lineal dimension, response time, velocity plot for constant pressure and tolerances proportional to dimension ratio.

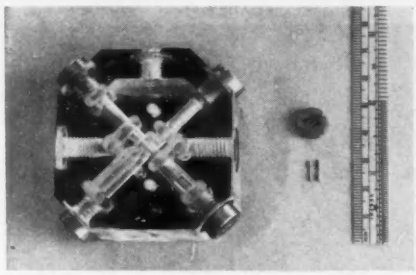
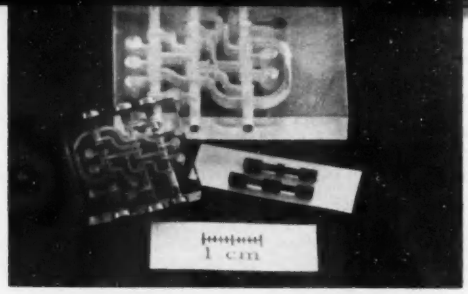
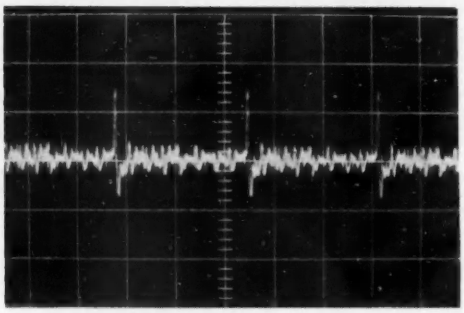


FIG. 5. Plexiglas multivibrators with bore diameters of 5 mm and 1 mm.



A



B

FIG. 6. A—Two single stage scale-of-two counters formed by using molded circuit technique. B—Pressure curve at output of four stage counter. Pressure fluctuations between well defined peaks do not represent noise but are due to pressure peaks generated by first three stages. Reflections can also be recognized.

Simple Calculations Show Performance Potential

In contrast to conventional power hydraulics, hydraulic logic elements operate unloaded (into a high impedance load). Fluid inertia and friction are the two factors that determine performance. The first depends on the length of channel over which the fluid is accelerated, while viscous forces in the gaps create fluid friction.

Basic calculations show the order of magnitude of these factors and lead to response time and power requirement estimates. Initial fluid acceleration is given by

$$a = p/\rho l$$

where l is the over-all channel length, p the absolute fluid pressure, and ρ the mean density of fluid and pistons over length l. Inserting the numerical values for a typical unit with a 20 cm channel length, 150 psia fluid pressure, and mean density of 1,000 kg/cm³ gives a fluid acceleration of 5,000 meters/sec². System response time can then be obtained from

$$t = \sqrt{2\,s/a}$$

where s is the small valve displacement required to switch fluid flow from one channel to another. For a displacement of about 2 millimeters the response time is 1 millisec.

These values can be checked against the limiting velocity derived from Bernoulli's equation

$$V_{lim} = \sqrt{2\,p/\rho}$$

Using the pressure and density given above, the limiting velocity is 45 meters/sec, well above the maximum velocity of 5 meters/sec reached in the element at the end of the 1 millisec response time. Viscous losses do not change the picture if a fluid of reasonably low viscosity is chosen. Also the small valve displacements are not likely to cause turbulence in the fluid, although this does not necessarily hold at high repetition rates.

The important conclusion is that valve displacements are so small that they do not influence the flow velocity V, provided the valve bore is not excessive. Thus branching of the fluid paths is possible, and compatibility of the hydraulic logic elements is not a problem.

Power consumption of these hydraulic units is small too. Energy per actuation is

$$E = ps(\pi/4)d^2$$

where d is the bore diameter. Thus this system with a 4 millimeter bore diameter requires only 25 millijoules or 25 milliwatts with a repetition time of 1 millisec. This is actually an idealized figure since it does not consider leakage, but it is illustrative of the high power/volume ratio that can be obtained in these hydraulic elements. Further savings in power consumption are possible by reducing the stroke and diameter.

This brief look does show that these hydraulic logic elements are comparable to conventional relays in operating speed and power requirements.

time is proportional to lineal size. Another advantage is in reduced power consumption: energy per actuation is approximately proportional to $(l/l_o)^3$. But the picture changes radically if tolerances are constant and independent of the reduction factor. The response time curves may now exhibit a minimum and no longer lie within the area bounded by the straight lines of Figure 4.

Experience shows that bores should not be below 1 millimeter in diameter, (usual manufacturing sizes lie between 1.5 and 2 millimeters). These conclusions and the curves of Figure 4 were confirmed by experiments on the two multivibrators shown in Figure 5. The lineal dimension ratio is five to one and the circuit is the same as that diagrammed in Figure 3B. With a 150 psi supply, the larger Plexiglas unit operates at 220 cps, while the smaller runs at 1,050 cps.

The small unit gives some idea of manufacturing and test difficulties. The best technique is first to build large scale models in Plexiglas and perform qualitative and quantitative experiments by stroboscope and high speed photography. Similarity then permits scale-down of the model if cavitation does not occur.

Cavitation shows up in varying ways. It can be unintentionally helpful by storing kinetic energy and so speeding up the element's operation. But it is equally likely, due to its stochastic nature, to cause frequency instability or jitter. Cavitation can cause erosion depending on materials and geometry.

Hydraulic arithmetic units for computation may be relatively distant but there are more immediate application possibilities for hydraulic logic. One would be to actuate the intake and exhaust valves of an internal combustion engine with a modified version of the counter in Figures 3D and 6. The unit has four stable states and would substitute for the step-down gears and the timing cams.

Minimizing Measurement Errors in NUCLEAR GAGES

- **LEVEL**
- **THICKNESS**
- **DENSITY**

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S. K. GHOSH, Dept. of National Health and Welfare, Canada

In absorption-type nuclear level, thickness, and density gages the need for accuracy of measurement depends on the gage's specific job. Errors can arise from several types of imperfections in the measuring system, from fluctuations in the radiation source, and from a nonlinear relationship between the detected radiation and the measured variable that occurs when the variable changes over a wide range of operating values.

The same type of error does not always have the same importance. Modulating level gages, for example, do not require extreme accuracy. Here, measuring system and fluctuation errors are generally insignificant. The major source of error is nonlinearity. Thickness and density gages, however, operate over such a narrow range that nonlinearity errors are trivial. Measuring system and source errors are the major barriers to high accuracy.

The level, thickness, and density gages described here operate on the principle that the material being gaged absorbs nuclear radiation. The absorber material is placed between a radiation source and a detector held rigidly at a fixed distance apart. Key problems are to determine the source strength, detector size, and spacing distance to reduce over-all measurement error, including nonlinearity, to a realistic and acceptable minimum.

Two basic equations apply to absorption-type nuclear gages. The first is

$$I = I_0 e^{-\mu\rho R} \qquad (1)$$

where I is the intensity of radiation falling on the detector after passing through the absorbing material, I_0 the intensity of radiation falling on the detector in the absence of absorber, μ the mass absorption coefficient, ρ the material's density, and R the actual radiation path length.

The second basic equation is that the radiation intensity I_0 is inversely proportional to the square of the actual radiation path R.

The significance of errors and typical design examples will be considered in detail for level, thickness, and density gages. The investigation of errors specific to the application derives from Equation 1.

Level gaging by nuclear radiation

The signal I from the level gage may be on-off to indicate the presence or absence of liquid at a specified level, or modulating to indicate actual fluid level. The particular configuration of source and detector, or geometry, depends on whether the signal is to be on-off or modulating, and, if modulating, on the acceptable linearity of signal.

As shown in Figure 1A, page 89, on-off level gages have their source and detector at the same level. Thus, for on-off level gaging there are only two extreme points of operation. When the liquid is below the reference level there is no absorber in the radiation path and, from Equation 1, $I = I_0$. When the measured fluid is at or above the source/detector reference height then $I = I_0 e^{-\mu\rho R}$.

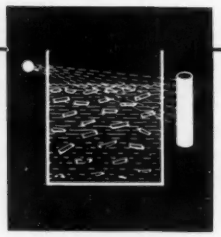
If $\mu\rho R$ is very large the signal is extinguished by the fluid and $I \to 0$; if $\mu\rho R$ is small the signal is proportional to the fluid and $I \to I_0(1-\mu\rho R)$.

In other words, as the liquid rises past the reference level the radiation intensity signal I drops sharply from a high value to a lower value. This two-value signal response for an on-off level gage is shown in Figure 1B. The lower value of signal intensity depends on $\mu\rho R$. Any error, then, arises from improper mounting of the detector and source.

For modulating level gages, the radiation signal intensity varies continuously with the level in some manner depending on the source/detector geometry and the factor $\mu\rho R$. Figures 2A, 3A, and 4A show three typical modulating level gage arrangements.

APPLICATION I

Modulating level gage



A modulating control system is required to hold the level of wood pulp to within 1 in. in an 18-in. diam tank. Over what range can this easily be done, and what geometry of source and detector should be used when the source is Cs 137?

Here,

$R \approx d = 18$ in. $= 46$ cm
$\rho = 1.0$ gram per cu cm (for wood pulp solution)
$\mu = 0.077$ sq cm per gram (for Cs 137)

Therefore, $\mu\rho R = 0.077 \times 1.0 \times 46 = 3.5$

From a comparison of the $\mu\rho R$ curves in Figures 2B and 4B, the extended source-and-detector geometry of Figure 4A appears to yield the better linear response. Drawing a chord across the $\mu\rho R = 3$ curve in Figure 4B, the maximum deviation from linearity is approximately $h/6$. Thus an accuracy of 1 in. can be maintained over a 6-in. range. In practice, a 12-in. long geiger tube detector and a point source is recommended. If a greater range is desired for the same accuracy, either a calibrated nonlinear response would have to suffice or nonuniform absorbers on the detector will provide desired linearity.

As can be seen, the signal intensity I vs height relationship for these configurations, Figures 2B, 3B, and 4B, differ considerably in their linearity and hence the output signal will include some error.

The four signal responses indicate that Figures 2A and 4A are basic geometries, that Figure 1A is a degenerate case of Figure 2A, and that Figure 3A is an approximation to Figure 4A. The arrangement in Figure 2A gives good linearity, hence minimum error, for very small values of $\mu\rho R$. Figure 4A gives good linearity for larger values of $\mu\rho R$.

By a suitable combination of the geometries in Figures 2A and 4A a substantially linear signal vs fluid level may be obtained for any given $\mu\rho R$. For instance, linearity can be achieved by steadily decreasing the strength along the strip source (or the sensitivity along the strip detector) in a predetermined nonlinear manner. In practice, this can be accomplished by a nonuniform absorber or collimator whose shape, which can be predicted by elaborate calculation, is probably best determined by a cut-and-try procedure.

Application I above considers a practical design problem for a modulating level gage.

Thickness gaging by nuclear radiation

Thickness and density gages are quite similar. They operate on the principle that the more the mass of material in the radiation path, the more the source radiation is absorbed. When the material's density is constant, the mass can be expressed as thickness; when the material's thickness is constant, the mass can be expressed as density.

The basis of nuclear thickness and density gages and the subsequent analysis of errors for such gages is obtained by rewriting Equation 1:

$$I = I_0 e^{-\mu x} \tag{2}$$

where x is the total mass of absorbing material per unit area.

Errors in measuring I cause errors in the determination of x. Just what the relationship is can be found by differentiating Equation 2:

$$\Delta I = -\mu I_0 e^{-\mu x}\,\Delta x$$

or

$$\Delta x = -\frac{\Delta I e^{\mu x}}{\mu I_0} \tag{3}$$

where ΔI is the error in measuring radiation intensity, then Δx is the resulting error in the measurement of the absorbing material's mass.

Equation 3 gives the absolute mass error. Dividing both sides by x yields the relative mass error:

$$\frac{\Delta x}{x} = -\frac{\Delta I e^{\mu x}}{\mu x I_0} \tag{4}$$

The art of gaging lies in minimizing Δx and $\Delta x/x$.

Uncertainties in measuring I, and hence in determining x, are due to imperfections in the measuring system and in the radiating source. The effects of individual errors for thickness gages (and some errors apply to density gages as well) are described in detail below.

Fluctuation error

A statistical uncertainty exists as to the number of individual particles or quanta being emitted from the radiation source in a given, short time interval, even though on a long time average they are being emitted at a definite rate. This uncertainty is called the fluctuation error Δn, defined as

$$\Delta n = \pm (n)^{1/2}$$

where n is the number of particles detected in a given time τ. Furthermore,

$$n = \tau E I$$

where E is the detector efficiency, the ratio of particles actually detected to particles incident on the detector. Differentiating the preceding equation:

$$\Delta n = \tau E \Delta I$$

Therefore,

$$\tau E \Delta I = \pm (\tau E I)^{1/2}$$

and

$$\Delta I = \pm (I/\tau E)^{1/2}$$

Substituting this value and Equation 2 into Equation 3 yields

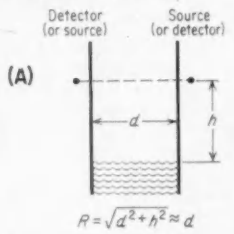
$$\Delta x = \pm \frac{e^{(\mu x/2)}}{\mu\,(I_0\,\tau E)^{1/2}}$$

where

$$I_0 = \frac{3.7 \times 10^7\, q \Omega S}{4\pi}$$

FOUR WAYS TO MEASURE LEVEL WITH NUCLEAR GAGES.

FIG. 1
ON-OFF
Single point source.



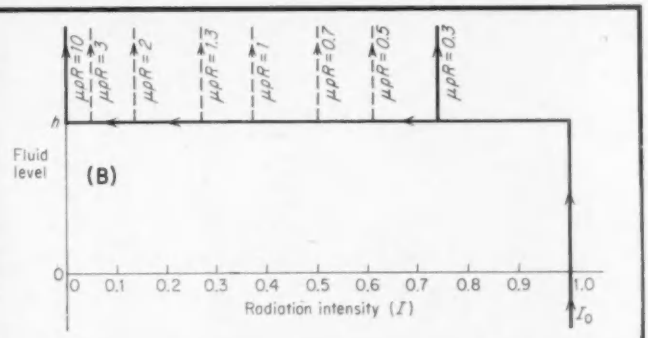
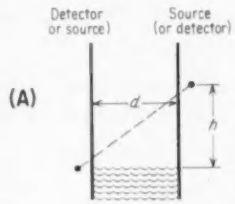


FIG. 2
MODULATING
Single point source.



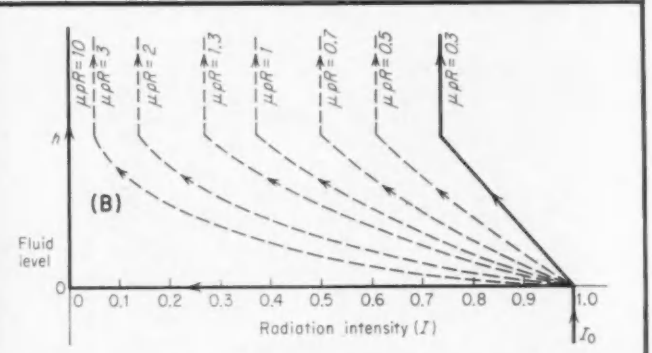
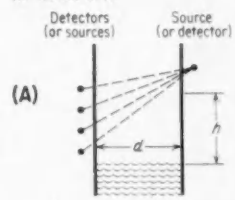


FIG. 3
MODULATING
Multiple point sources
(or detectors)



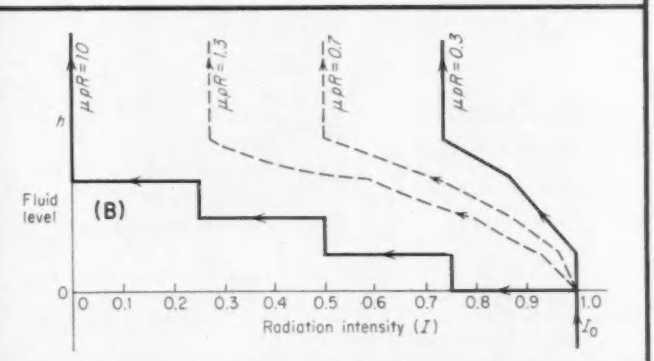
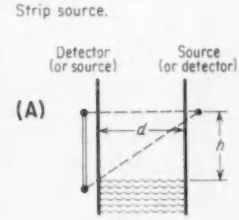
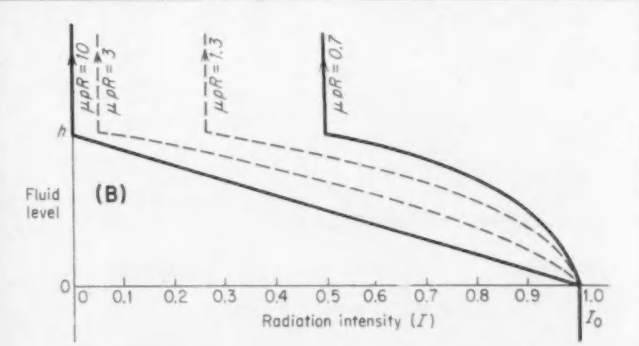


FIG. 4
MODULATING
Strip source.





S = source activity in millicuries
Ω = solid angle of radiation subtended by the detector
q = the number of β particles (or γ quanta) produced per disintegration

As a result,

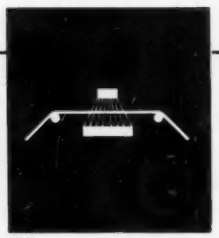
$$\Delta x = \frac{e^{(\mu x/2)}}{\mu\,(3.0 \times 10^6\, q\Omega S\tau E)^{1/2}} \qquad (5)$$

and

$$\frac{\Delta x}{x} = \frac{e^{(\mu x/2)}}{x\mu\,(3.0 \times 10^6\, q\Omega S\tau E)^{1/2}} \qquad (6)$$

A quick look at Equations 5 and 6 indicates that the absolute and relative mass errors will be minimum when q, S, Ω, τ, and E are maximum. More to the point, however, is finding the dependence of fluctuation error on μ and x. This can be done by differentiating Equations 5 and 6 with respect to x and μ, and equating the results to zero. In each case, the condition for Δx and $\Delta x/x$ to be minimum is that $\mu x = 2$, except that the absolute mass error will be minimum when $x = 0$. The relationship $\mu x = 2$ satisfies the condition for a maximum signal-to-noise ratio for the three cases. In practice, there may not be too much option in the value of x or μ.

Application II works out an example in which an allowable fluctuation error is stipulated, and the problem is one of selecting a source strength that meets this requirement.



APPLICATION II
Thickness gage source strength

Assuming a detector efficiency of 20 percent and a solid angle subtended by the detector of 15 percent, how many millicuries of Kr 85 are required to measure 0.00025-in. thick aluminum foil with a fluctuation error of only 1 percent, for a measuring time of A) 1 sec, and B) 10 sec?

The following values apply:

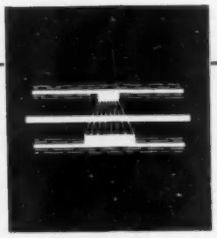
$\frac{\Delta x}{x} = 0.01$

$x = 0.00025 \times 2.54 \times 2.7 = 1.7$ milligram per sq cm
$\mu = 0.026$ sq cm per milligram (for Kr 85)
$q = 1.0$
$\Omega = 0.15$
$\tau = 1$ or 10
$E = 0.20$

Inserting these numbers in Equation 6,

$$0.01 = \frac{e^{0.026\times1.7/2}}{0.026\times1.7\,(3.0\times10^6\times1\times0.15\times S\times1\times0.20)^{1/2}}$$

Therefore, A) S = 60 millicurie for τ = 1, and B) S = 6 millicurie for τ = 10.



APPLICATION III
Thickness gage spacing error

When the effective distance between source and detector is 4 in., what is the absolute mass error introduced by increasing the spacing by 0.005 in. when the source is A) Sr 90, and B) Kr 85? (Such a situation may arise, for instance, when source and detector are mounted on separate tracks and vibrate or displace independently.)

The radiation intensity at the detector varies inversely as the square of the distance to the source. Thus, if the intensity at the detector is initially I, the intensity after the distance is increased by 0.005 in. becomes

$$\left(\frac{4.000}{4.005}\right)^2 I = I/1.0025$$

Since $\Delta I = kI$, where k is a system constant, then

$$k = \Delta I/I = (1.0025 - 1.000)/(1.000) = 0.0025$$

From Equation 7 in the text,

$$\Delta x = -(k/\mu) = -(0.0025/\mu)$$

A) For Sr 90, μ = 0.0062 sq cm per milligram. Therefore,

$\Delta x = -(0.0025)/(0.0062) = -0.4$ milligrams per sq cm.

B) For Kr 85, μ = 0.026 sq cm per milligram, and

$\Delta x = -(0.0025)/(0.026) = -0.1$ milligrams per sq cm.

Apparatus errors directly proportional to radiation intensity

A group of apparatus errors directly proportional to the radiation intensity at the detector include variation in the source-to-detector spacing, source decay, gas leaks in the detector's ion chamber, voltage variations on the ion chamber, and input resistor variations. These errors may be lumped in the factor k, so that

$$\Delta I = kI$$

and

$$kI_0e^{-\mu x}$$

from Equation 1.

Substituting the above expression into Equations 3 and 4 yields

$$\Delta x = -(k/\mu) \qquad (7)$$

$$\Delta x/x = -(k/\mu x) \qquad (8)$$

An examination of Equations 7 and 8 shows that the absolute and relative mass errors due to apparatus variations decrease as μ increases. Furthermore, while Δx is independent of x, $\Delta x/x$ decreases as x increases. However, increasing x or μ indefinitely is not always practical; doing so may increase the fluctuation error to a dominant role in the total error.

One way of minimizing apparatus error without

increasing x or μ unduly is to use a balanced system, in which a second source and detector are automatically balanced in bridge relationship against the "measure" source and detector. The balanced system removes most errors due to apparatus variations, although variations in the source-to-detector spacing and leaks in either ion chamber can still cause trouble unless otherwise removed.

Application III shows how to calculate the error in reading absolute mass caused by a variation in the distance between detector and source.

Foreign material error

A troublesome error often arises because of extraneous material of uncertain mass lodging in the measuring gap of a thickness gage. Two prime offenders are atmospheric air (which is subject to a change in density because of temperature and pressure changes) and material building up on the protective windows.

Errors of this class are described by

$$\Delta I = k\mu I$$

which, when substituted into Equations 3 and 4, gives

$$\Delta x = k \tag{9}$$

$$\Delta x/x = k/x \tag{10}$$

where k equals mass of foreign matter introduced. Equations 7 through 10 are equally valid for nuclear density gages.

While no choice of parameter (except a smaller air gap or a balanced system) can reduce the absolute mass error due to foreign matter, the relative error decreases as x increases.

Application IV gives a practical demonstration of the error introduced by foreign matter in the air gap between source and detector.

Apparatus errors independent of radiation intensity

A few thickness gage errors are independent of radiation intensity. Among these are leakage current across the ion chamber insulation and grid current in the input tube. Substituting $\Delta IE = k$ (a constant) into Equations 3 and 4 yields the appropriate equations with which to investigate this class of errors:

$$\Delta x = \frac{ke^{\mu x}}{\mu I_0 E} \tag{11}$$

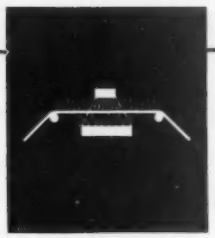
$$\frac{\Delta x}{x} = \frac{ke^{\mu x}}{x\mu I_0 E} \tag{12}$$

Note that, as with fluctuation error, both mass errors are minimized by increasing those factors comprising I_0 (q, Ω, S) and E; and that Δx is a minimum when $x = 0$. Again, differentiating the preceding equations to see how the absolute and relative mass errors depend on μ and x it is found that minimum errors occur when $\mu x = 1$. That is, $\Delta x/x$ is a minimum when $x = 1/\mu$; Δx and $\Delta x/x$ are both minimums when $\mu = 1/x$. The relationship $\mu x = 1$ satisfies the condition for maximum signal in the gage for a given change in mass.

Errors of unknown dependence

Some errors are not easily identified with common system parameters. Here, empirical development can be more fruitful than theoretical analysis. Two such errors are 1) that due to the position of the absorbing material in the measuring gap, which can be greatly reduced by suitable experimental collimation of source and detector; and 2) that due to the material's composition, which can be reduced by trying special absorbers in the radiation beam.

Though treated as a constant, μ for a beta or gamma ray gage varies to some extent on the geometry of the source-and-detector arrangement, on the construction of the detector itself, and on the thickness and composition (i.e., atomic number) of the material being measured. However, with careful design these effects can be minimized. As the following table shows, a beta ray gage with an uncollimated source and detector can be built having a total variation in μ of only 1 to 2 percent, so that μ is essentially constant for such materials as paper, plastic, aluminum, rubber, and steel. Minimizing the composition effect is more difficult for a gamma ray gage, especially for heavy elements. The table also gives values of μ for three common gamma ray sources, for a number of materials.



APPLICATION IV

Foreign matter error

What error is introduced, in a newsprint thickness gage with a 1-in. source detector air gap, by a change in air temperature from 90 to 110 deg F?

Newsprint weighs 5 milligram per sq cm. From Equation 9 in the text, $\Delta x = k$, it is seen that absolute mass error is independent of both μ and x. In fact, the absolute mass error simply equals the change in mass. Thus, since a column of air changes from 2.94 to 2.84 milligrams in going from 90 to 110 deg F, the absolute mass error is −0.10 milligrams. The relative mass error is 0.10/5.0 = 2 percent.

Density gaging by nuclear radiation

For a variety of reasons the gap between source and detector of the thickness gage is essentially independent of the thickness of the material being measured. An attempt is made to optimize all

NUCLEAR SOURCES FOR GAGING.

BETA RAY SOURCES	μ (sq cm per milligram)
Promethium-147	0.131
Krypton-85	0.026
Strontium-90	0.0062

GAMMA RAY SOURCES	μ (sq cm per gram)			
	Water or oil	Aluminum	Steel	Lead
Iridium-192	0.105	0.102	0.105	0.31
Cesium-137	0.077	0.074	0.072	0.103
Cobalt-60	0.055	0.053	0.051	0.055

other conditions so as to minimize errors. However, for minimizing errors in density gaging, the source-to-detector spacing can and must be optimally chosen for the application.

The solid angle Ω subtended by the detector at the source is

$$\Omega = \frac{A}{\left(\frac{x}{\rho} + B\right)^2}$$

where A is the area of detector in the radiation beam, and B is the minimum center-to-center distance between detector and source (both outer cases in contact and no absorbing material between them). Thus, the case-to-case spacing x/ρ depends on the measured mass.

Fluctuation error

Substituting the preceding relationship between spacing and mass into Equations 5 and 6 gives the two mass errors in density due to fluctuation:

$$\Delta x = -\frac{\left(\frac{x}{\rho} + B\right) e^{\mu x/2}}{\mu\,(3.0 \times 10^6\, qAS\tau E)^{1/2}} \qquad (13)$$

$$\frac{\Delta x}{x} = -\frac{\left(\frac{x}{\rho} + B\right) e^{\mu x/2}}{\mu x\,(3.0 \times 10^6\, qAS\tau E)^{1/2}} \qquad (14)$$

Equation 13 shows that Δx is minimum when $x = 0$. Differentiating the right-hand sides of Equations 13 and 14 with respect to μ and equating to zero shows that, for a given x, Δx and $\Delta x/x$ are minimums when $\mu = 2/x$ (just as for the thickness gage). However, differentiating Equation 14 with respect to x and equating to zero yields the conditions for minimum $\Delta x/x$, given μ, as,

$$x = \rho\left[-\frac{B}{2} + \left(\frac{B^2}{4} + \frac{2B}{\mu\rho}\right)^{1/2}\right] \qquad (15)$$

Equation 15 is the maximum signal-to-noise relationship for nuclear density gages.

Application V is a problem in which optimum pipe diameter depends on the fluctuation error.

Apparatus errors independent of radiation intensity

The relationship between spacing and mass, when substituted into Equations 11 and 12, yields

$$\Delta x = -\frac{k\left(\frac{x}{\rho} + B\right)^2 e^{\mu x}}{3.0 \times 10^6\, qAS\mu E} \qquad (16)$$

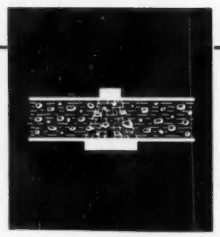
$$\frac{\Delta x}{x} = -\frac{k\left(\frac{x}{\rho} + B\right)^2 e^{\mu x}}{3.0 \times 10^6\, qAS\mu x E} \qquad (17)$$

Here, Δx is a minimum when $x = 0$. Differentiating Equations 16 and 17 with respect to μ gives $\mu x = 1$ as the condition for minimum Δx and $\Delta x/x$ for a given x.

Differentiating Equation 17 gives

$$x = \frac{\rho}{2}\left\{-\left(\frac{1}{\mu\rho} + B\right) + \left(\left[\frac{1}{\mu\rho} + B\right]^2 + \frac{4B}{\mu}\right)^{1/2}\right\} \qquad (18)$$

as the condition for $\Delta x/x$ to be minimum for a given μ. Equation 18 is the maximum signal relationship for nuclear density gages.



APPLICATION V
Optimum pipe diameter

Ore slurry is to be monitored by a density gage. What is the optimum diameter of the sample-stream bypass pipe if the slurry has an average density of 2.d grams per cu cm, and the gage performance is limiten by fluctuation error? The gage uses an ionizati chamber detector (B = 16 cm) and a Cs 137 source.

Since this is a problem of getting a maximum signal-to-noise ratio, Equation 15 applies. Thus,

$$x = \rho\left[-\frac{B}{2} + \left(\frac{B^2}{4} + \frac{2B}{\mu\rho}\right)^{1/2}\right]$$

where B = 16 cm; μ = 0.075; ρ = 2.0 grams per cu cm. **Therefore,**

$$x = 2.0\left[-\frac{16}{2} + \left(\frac{256}{4} + \frac{32}{2\times 0.075}\right)^{1/2}\right] = 17.8 \text{ gm/cm}.$$

and the pipe diameter x/ρ = **17.8/2.0 = 8.9 cm = 3.5 in.**

When the major gage error arises from small signal strength then the problem is one of determining the optimum pipe diameter to yield maximum signal. Here, Equation 18 applies.

Television Switching Control

E. J. SCHUBERT
Monitor Systems, Inc.*

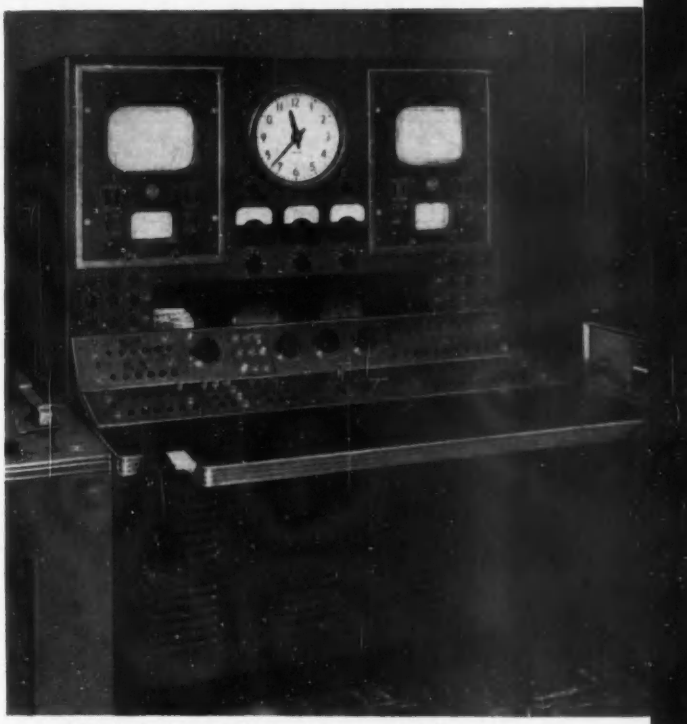


FIG. 1. RCA control console in use at WCAU-TV, Philadelphia, has electromechanical memory.

Few people outside the broadcasting industry realize the complex switching that goes on during and between TV shows. Here author Schubert blocks out a special purpose computer that can store switching sequences for one day of TV programs and carry them out in synchronization with real time. Its operational keyboard with selection logic does away with coding and cuts human errors.

Television program production involves a multitude of precisely coordinated switching sequences, particularly during station breaks and commercials. Audio and video signals from magnetic tape units, film and slide projectors, and from one or more studios must be selected and combined accurately in quick succession. The nightmare plaguing TV control room people is that an error might occur during a commercial sent out with a nationwide program or during any part of an expensive color show. To avoid such pitfalls, compromises like video tape and intermediate sound movies are widely used. When a program is done "live", the necessary precautions make for poor utilization of auxiliary equipment and excessive waiting time for performers and technical personnel.

What is needed, especially at key network stations, is some form of stored program capability in the control system. Program preparation and automatic checkout prior to actual performance would drastically reduce the probability of errors. It should also be possible to operate with fewer tape players and projectors, reducing the necessary investment in program source equipment.

A few stations are now using control consoles with a limited amount of electromechanical storage capacity. The control console, Figure 1, allows a maximum of three presets for the succeeding TV schedule. Circuits in use and pending are indicated by illuminated push buttons. Punched tape programmers have been tried, but they are not flexible enough for subroutines and their program preparation is a lengthy process. A much better television control system can be made using a magnetic memory drum and other digital computer techniques.

General requirements

The operator of a stored program system would be expected to prepare the program by manual entries on a keyboard and transfer it into the memory. Conventional keyboards require the operator to use codes of one sort or another. No matter how simple, such codes give rise to the occasional insertion of wrong commands. It is highly desirable to

* Now a private consultant in Pasadena, Calif.

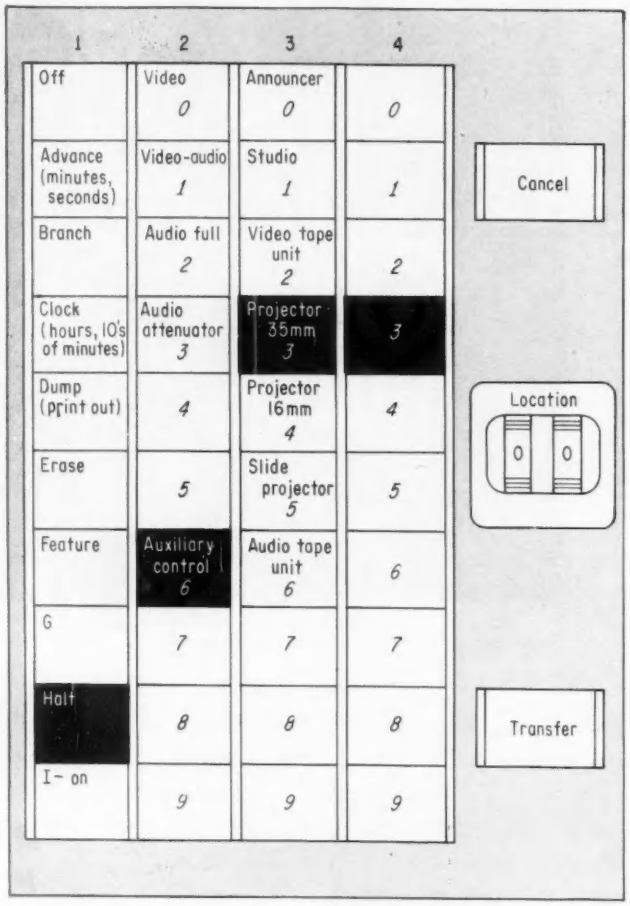


FIG. 2. An operational TV switching keyboard.

TYPICAL TV SWITCHING SEQUENCE

A feature film is in progress, and the last command (shown punched on the keyboard of Figure 2) was H 633, halt for a marker signal from 35-mm projector 3.

Time	Program	Command	Remarks
6:44:00	End of movie	O 133	Switch off 35-mm proj. 3.
	Film commercial	I 141	Switch on 16-mm proj. 1.
		A 045	Advance 45 sec.
6:44:45		O 141	Switch off 16-mm proj. 1.
	Station break	I 052	Switch on slide proj. 2.
		I 261	Switch on tape unit 1.
		H 699	Halt for minute tin ing signal.
6.45:00		O 052	Switch off slide proj. 2.
		O 261	Switch off tape unit 1.
	News	I 051	Switch on slide proj. 1.
		I 262	Switch on tape unit 2.
		A 015	Advance 15 sec.
6:45:15		O 051	Switch off slide proj. 1.
		O 262	Switch off tape unit 2.
		I 111	Switch on audio/video studio 1.
		H 611	Halt for marker from studio 1.
		etc.	

Ax	ADD content of memory location *x* into C register.
Cx	CONDITIONAL TRANSFER execute command in memory location *x* if content of C register is negative; otherwise continue with next step.
H-	HALT the machine for keyboard entry.
Hx	HALT for signal on line *x*.
Ix	SWITCH ON control line designated by address *x*.
K-	KEYBOARD transfer into next memory location.
Ox	SWITCH OFF control line designated by address *x*.
P-	PRINT content of *A* register.
R-	READ content of the next memory location into *A* register.
Sx	SUBTRACT content of memory location *x* from content of *C* register.
Ux	UNCONDITIONAL TRANSFER to memory location *x*.
Wx	WRITE content of *C* register into location *x*.

have a keyboard with keys labeled identically to the switching terms normally used by the operator. Keys should be interlocked so that irrational commands will be signaled to the operator rather than being put in the memory.

Using the same keyboard for program preparation and operational control may be tolerated but is not recommended because of possible conflicts during emergency conditions. The operator should be able to concentrate on program preparation without being distracted by simultaneous monitoring or control of a program on the air.

Extensive experience with business data processing systems has shown that human errors in data preparation outnumber equipment malfunctions by several orders of magnitude. No error-correcting code in the machine will prevent the operator from entering wrong data. Most important are good design of the keyboard and the display and recording devices for keyboard entries and memory content to improve communication between the operator and the system. Stored subroutines should be used for recurring sequences such as station breaks comprising recorded commercials, and news or movies with interlaced commercials. Automatic slide projectors, film projectors, and tape recorders can then be used in a permanent setup which is called out on demand by the main program.

Using a general purpose computer

Almost any small general purpose computer, such as a stripped down version of

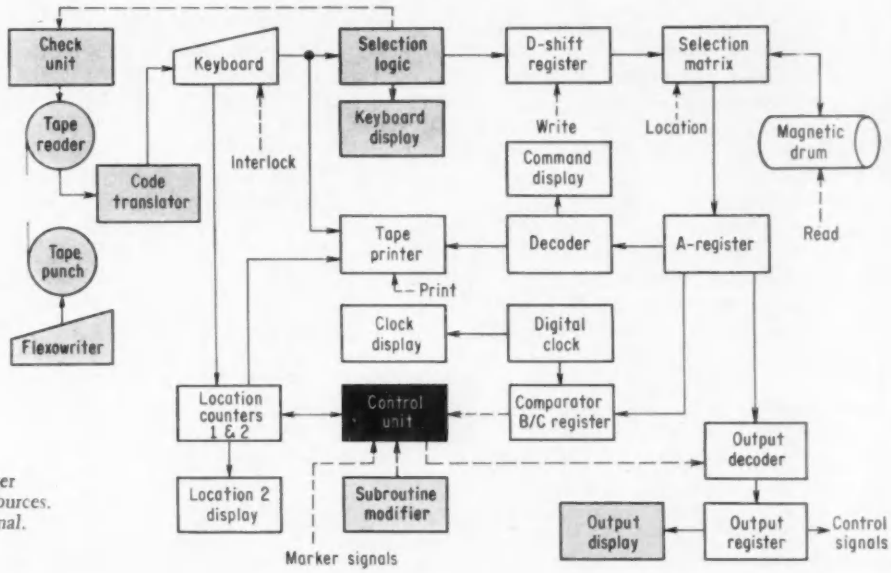


FIG. 3.

Special purpose computer switches TV program sources. Shaded parts are optional.

the early Burroughs E101, could be used for TV switching control. Such simplified computers may have a comparator instead of a conventional arithmetic unit. This comparator subtracts a number in the *B* register from the content of the *C* register and yields the difference in the latter. The internal single address commands listed at the top of the preceding page will suffice.

Only the SWITCH ON and SWITCH OFF commands do not normally exist. A digital machine equipped with these instructions is capable of operating in real time synchronization with a stored program. The SUBTRACT command compares programmed time delays or times with real time.

If an event is defined as the transition from one state of the external control lines to another, the required switching speed will usually not exceed one event per sec. Each event might involve at most six ON signals following a general OFF command. During the minimum time of 1 sec, several comparisons might be required to establish time coincidence. Then at most seven command words have to be read out and transferred to the control lines. Any electronic digital computer can handle this amount of data processing easily. The major limitations of general purpose machines are the lack of output control lines and the need for an operator trained in computer coding.

Special purpose TV switching computer

A practical control system should respond to operational commands instead of arithmetic or logical instruction as listed above. Figure 2 shows an operational keyboard which might be used, and Figure 3 is a block diagram of a suitable computer. Commands are in the form of a four decimal digit word, the first digit being interpreted as a letter. The operator selects one key in the first column, then one each in the second, third, and fourth.

Using such a keyboard implies a stored macroprogram of internal instructions. For example, the operational command to ADVANCE after 5 min, 15 sec, might initiate this internal macroprogram:

R-	READ *content of next memory location into A register.*
Axxx	ADD *content of location xxx (515) into C register.*
W001	WRITE *content of C register into location 001 (time counter).*
H002	HALT *for signal on line 002 (time counter at zero).*
R-	READ *content of next memory location into A register.*

After the command has been entered, the operator depresses the transfer key, and data flows from the keyboard to the *D*-shift register where it is stored until a write command is received from the control unit. Meanwhile, an interlock prevents entry of new data into the keyboard. As soon as the selection matrix is available and no switching commands are being carried out, data flows serially from the *D*-shift register via the selection matrix into the magnetic drum in location *X* (retained in location counter 1). Both the location and the data are recorded on a tape printer.

The table outlines a typical switching sequence. The tabulation under "Command" is the data entered by the operator. This information and the corresponding memory locations are printed on the tape record.

Referring again to Figure 3, location counter 2

indicates the memory location of the pending command. This is visible to the operator on the command display. Only a HALT command or an ADVANCE or CLOCK command for time T will be retained in the command display since other switching commands are processed at maximum rate and will not be visible. The digital clock represents real time t and pretimes such as t plus 10 sec if required. Pretime instructions for the equipment requiring prestarting is stored in the computer. Additional displays for remaining time can be installed in studios.

In time dependent operation, a timing command always precedes a switching command. At coincidence between command time T and real time t (or t plus 10 sec in the case of a prestart) the comparator sends a go signal to the control unit. The control unit then initiates a READ command for the information in the memory location retained in counter 2 into the A register. The command in the A register is decoded and if it is a switching command a control signal is posted into the output register relay bank.

Switching can also be dependent on a marker signal received over a signal line. In this mode of operation the switching sequence is stopped by a HALT command which specifies the line on which the marker has to be sensed. The marker might be a signal of minus 10 volts and at least 10 microsec duration. On its arrival the control unit initiates a go signal, and the rest of the operation is as above.

An error in memory location xy can be corrected in either of two ways. An ERASE command specifying the location xy as recorded on the tape will blank out the instruction, or another command can be written into the same location xy. A double word BRANCH instruction will be interpreted as such if the first column of the second word is not selected, e.g., BRANCH 347, 615. The auxiliary keyboard switches marked location can be used to specify up to five digits of the memory location number. The new sequence can be terminated with either a HALT or another BRANCH command as desired.

Under normal circumstances no memory dump is required since the system produces a printed record at the time of data entry. The dump function becomes more important, however, when subroutines are used. The double word command DUMP xy, z specifying up to five digits each of two memory locations will generate sequential printout of the memory content between these locations. Memory dump is a low priority function and will be interrupted whenever control signals are generated or new data is to be entered.

Optional features

KEYBOARD SELECTION LOGIC. A keyboard with color coding and constraints in data selection can be provided as an option and is recommended. Green is used for permissible selections, and amber for accepted ones. When the keyboard is ready for data entry the left column of buttons lights green, indicating that any of them may be pressed. Pressing a key changes it from green to amber, extinguishes the other keys in this column, and lights the permissible choices in column 2 in green. Pressing one of these keys lights the possible selections in column 3, etc. If the fourth column selection is unpermitted, the green light in the TRANSFER key will not come on and the incorrect key will not lock.

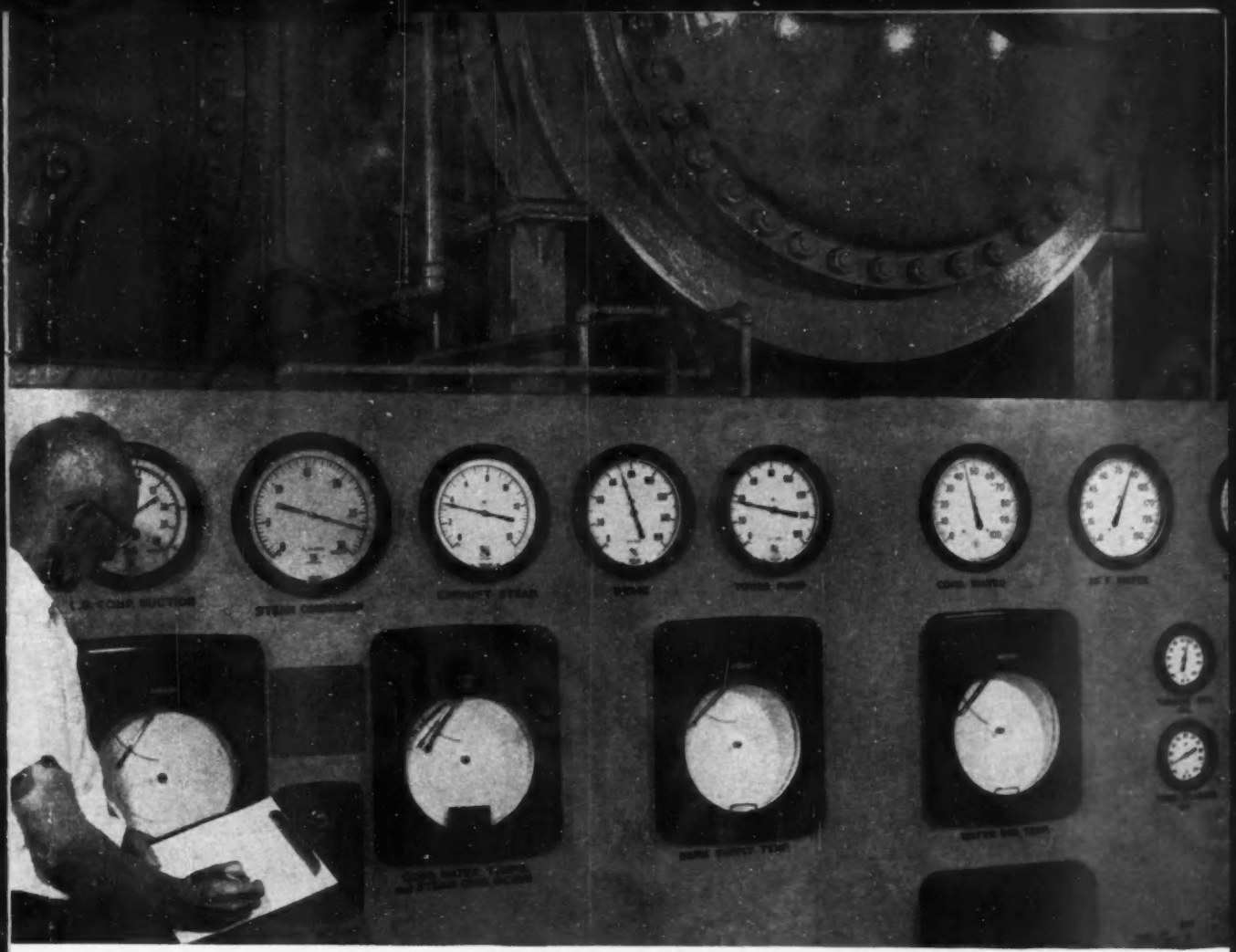
POSITIVE OUTPUT CONTROL AND DISPLAY. The standard output register provides momentary contact closures about 0.2 sec long which trigger changes of state on the control lines. For greater reliability the on or off condition of a line should be defined by discrete signals, and an optional output register will provide contact closures lasting until a corresponding off signal is given. Additional output display units are also optional.

SEPARATE PROGRAM PREPARATION EQUIPMENT. An operator cannot use the built-in keyboard continuously because his action is restricted by the computer's simultaneous control functions. Preparing the program on an independent Flexowriter is more efficient and provides a written record for checkout which is not available from keyboard entries. (At the time the built-in tape printer produces a record of the stored commands any errors are already in the memory and require separate instructions for correction.) The same check functions performed by the keyboard selection logic can be provided plus the necessary translator from Flexowriter code to computer commands.

SUBROUTINE MODIFIERS. Proper use of subroutines can greatly simplify the insertion of a full day's switching instructions. The program will consist of a sequence of features with proper setup identifications which define subroutine modifiers. Subroutines can also be used for alternative instructions prepared in advance for unpredictable conditions such as a movie being too short or too long for the assigned time. This will relieve the operator and provide smoother operation.

The relatively slow speed (by computer standards) of TV switching sequences lends itself to serial computer technique. Serial machines cost less and use impressively less hardware than those handling data in parallel. Reliability is increased, and trouble shooting and preventive maintenance requirements are simplified. If the system is built with solid state electronics and a conservatively designed magnetic drum, preventive maintenance might require at most two hours for every 800 hours of continuous operation. Since the system sits idle most of the time (between switching commands), the probability of failure is further reduced. Excessive demands for computer reliability are not justified. Because of the less reliable and numerous electromechanical devices connected to the programming system the improvement in system reliability would be negligible.

Switching control systems of this type seem to be similarly promising for motion picture production.



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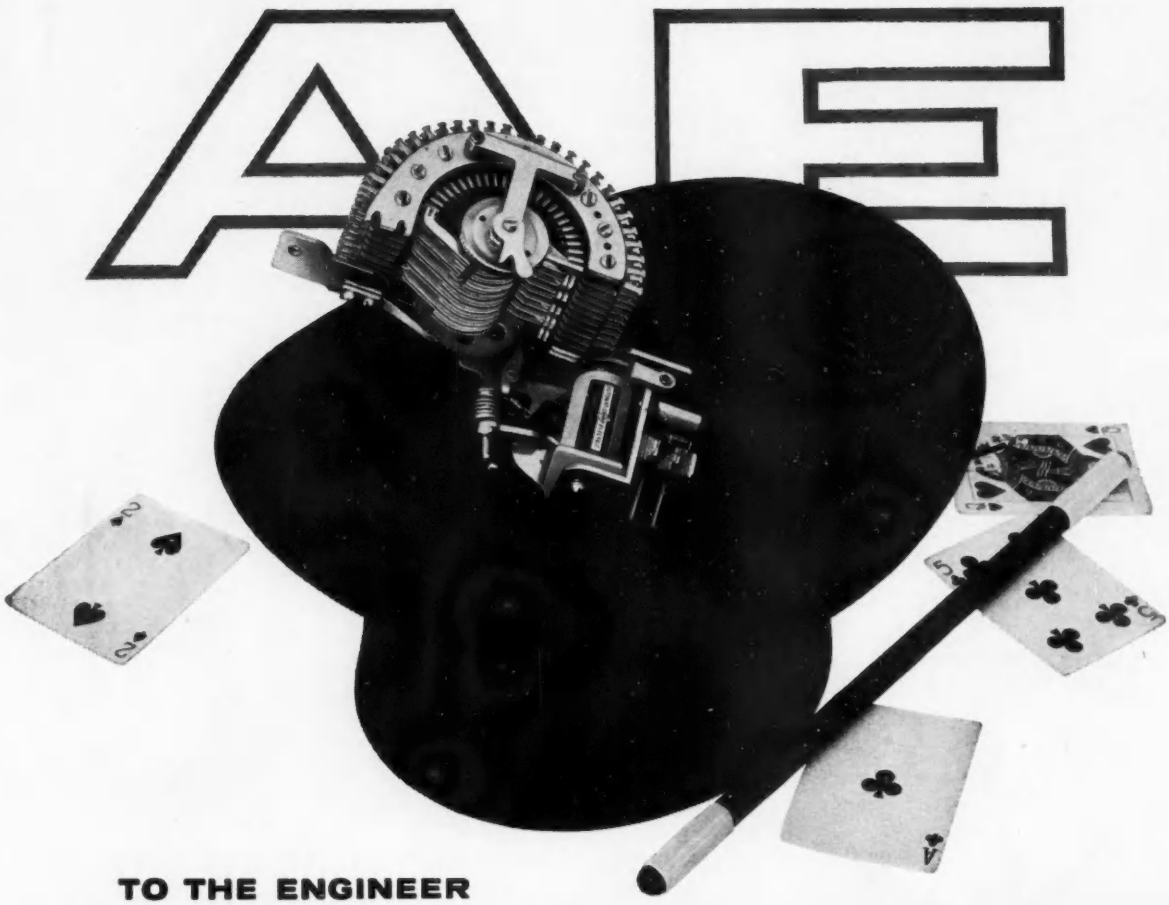

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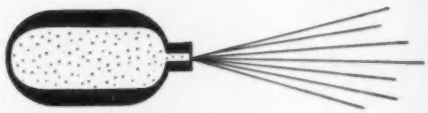


HOT GAS CONTROL SYSTEMS—II

Designing a Hot Gas Servoactuator

THE GIST: Servoactuator hot gas controls are used to position an aerospace vehicle's aerodynamic control surfaces or thrust nozzles. Designing these controls requires a clear understanding of how they differ from hydraulic servos. With knowledge of hot gas system components, fuels, and materials, the designer can use conventional servo design techniques —including analog computer simulation—to solve a given control problem.

H. A. POOLE, JR.
E. A. DEMERS
Walter Kidde & Co., Inc.

Several subsystems may be integrated in a gas-operated secondary power system for a flight vehicle, but invariably the flight controls set the test of performance. Either a servoactuator control, which receives a guidance signal and alters the aerodynamic characteristics of a control surface or positions a thrust nozzle, or a reactive system, which produces reactive thrust vectors for attitude control, faces difficult specifications. A combination of the necessary fast response, reliability, and extreme accuracy coupled with unpredictable loads, limited space, and rough environments demand tough requirements.

Here a chosen servoactuator problem and the steps toward system design are discussed. The approach to the design of the reactive system will be discussed in the final part of this series.

A gas servo is not a hydraulic servo, and the same rules do not necessarily apply (Ref. 1). For instance, the low open-loop natural frequency of the uncompensated gas servo is a function of the equivalent bulk modulus of the gas (Ref. 2). It is considerably lower than the natural frequency of a similar hydraulic servo, so controlling the dynamic response of the gas servo will be more difficult because of compressibility of the medium. The pneumatic control system's behavior under high friction loads is also quite different from hydraulic behavior. Compressibility allows considerable excess accelerating forces at the instant of release of breakaway friction. The tested dynamic response can be sensitive to the amplitude of the command signal as well as the magnitude of the friction load itself. Proper compensation eliminates these loading effects.

Once set on the right track of gas system design, the special characteristics of hot vs cold gas become important. The advantages of higher specific impulse, storability, and lower bulk and the offsetting disadvantages of temperatures and dirtiness of the hot gas must enter into the choice for a specific job.

Establishing a typical problem

Typical load requirements for missile control systems can differ widely. Rocket nozzle positioning applications can vary from a large, sluggish missile to a small, nimble, and highly accurate one. Mass moment of inertia of the former can be about 16 lb-in.-sec^2; of the latter, about 0.1 lb-in.-sec^2. Maximum hinge moment can be 18,000 lb-in. for the larger missile system and 400 lb-in. for the smaller. Response (plus or minus 3 db amplitude) can be required to be 3 cps for the slower system but 10 cps for the more nimble one. Aerodynamic control surface moments of inertia and hinge moments vary similarly; frequency response would have to be 5 cps for the large missile and 15 cps for the smaller. Friction torque for the nozzle positioner (4,800 lb-in. for the larger, 250 lb-in. for the smaller) is so small that it is not a primary consideration here, although it may be critical in the final design.

The fast response requirements of the aerodynamic control surface with the friction loading of a nozzle thrust positioning control in a small missile illustrate many factors in the synthesis and design of a total hot gas system. Figure 1 shows a canard control of an air-to-air missile, the system studied here. The specification for this system is given in the table; it serves as a guide for the design.

Selecting the power source

The optimum power source chosen is a relatively slow-burning solid propellant with a good high tem-

THE MISSILE AND ITS CONTROL SPECIFICATIONS

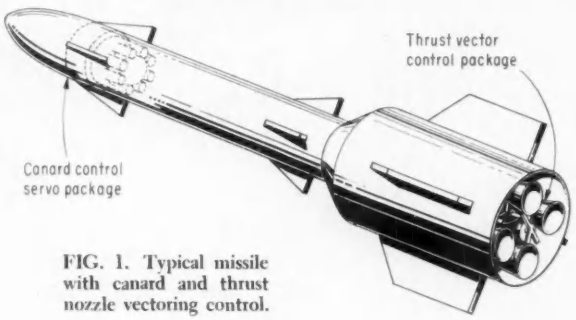


FIG. 1. Typical missile with canard and thrust nozzle vectoring control.

TABLE—CANARD CONTROL SPECIFICATION
(Modified for High Friction)

Flight duration	80 sec
Ambient temperature (operating)	−65 to +1,400 deg F
Ambient temperature (nonoperating)	−65 to +160 deg F
Storage life	Up to 5 years
Storage temperature	−65 to +200 deg F
Controls required	four surfaces, one servo each
Gas generator	one generator, manifolded
Checkout testing	Monthly and prelaunch, with air
Total travel of surface	25 deg
Maximum velocity at ½ load	100 deg/sec
Mass moment of inertia	0.5 lb-in.-sec^2
Maximum total hinge moment	3,100 lb-in.
Friction load, running	500 lb-in.
Friction load, breakaway	600 lb-in.
Aerodynamic spring rate	200 lb-in./deg
Maximum trim moment	800 lb-in.
Amplitude at ±2-deg input	within ±3 db at 10 cps
Phase response at ± 2-deg input	90-deg phase lag at 10 cps
Transient response to max input	Less than 25 percent overshoot
Resonance	None at less than 20 cps
Attenuation	Down more than 15 db at 30 cps
Resolution sensitivity	0.35 deg
Reliability of systems fired	0.991
Total system weight	Minimum compatible with performance

perature storage history and high reliability, used in previous systems, if possible. It should be clean burning, but the corrosive nature of its byproducts will not be a limitation because of the short duration called for by the specification in the table. Flame temperature can be important. The propellant most suited is an ammonium nitrate-based grain of approximately 170 sec specific impulse and a flame temperature of 1,800 deg F. Since the inhibitor can contribute much of the undesirable matter that causes the valving to fail, it is important to study the inhibitor as well as the grain. Combining an improved inhibitor with the grain selected produces a propellant that is quite satisfactory for gas servo use at the 1,000-psi pressure that is optimum for the design system.

The major arguments leading to these choices can be considered in this way:

• **Operating period and power**—The brief flight period and relatively great power level stated in the specification are the primary factors that dictate a propellant or high pressure stored gas system. The weight of the system of pressure vessel, valving, and mounting brackets for a high pressure nitrogen system—considered optimum for a noncryogenic supply—needed to fulfill the control requirements will be considerably more than the weight of a propellant system. Since the specific impulse of a medium is related to its gas generating efficiency (Ref. 3), the relatively low impulse cold gas systems will only compete with hot gas for low-power applications or in extreme environments. However, the low-power advantages of the cold gas system may also be challenged by the simplicity of a catalytic start monopropellant (like hydrogen peroxide), but only for long flights.

• **Storage time and temperature**—As given in the specification, these eliminate most monopropellants and some cleaner burning solid propellants. Bipropellants have not been considered because of the complexities added by valving, handling, storage, and cooling. Hydrogen-oxygen generators have been tested, though, for auxiliary power, hot gas servo, and totally integrated space vehicle systems (Ref. 4). Without cooling, the high ambient temperature would throw out all hot gas servo propellants, if it were not that the high operating temperature were experienced for such a brief time. Thermal lag is inherent in the mass of the servomotors and the gas generator, so only a modest amount of insulation or shielding is needed.

• **Reliability**—This is the greatest factor influencing the choice among the propellants not yet eliminated. It might be so important that a heavier system involving stored gas or even a large gas filtering-processing element in the hot gas line would have to be used. Even overlooking the storage and temperature limitations of the favorite monopropellants—hydrazine, Dynathene, and hydrogen peroxide—their long-term operating capabilities are unnecessary for the short flight of this problem and require overly complex systems. One advantage in reliability of the monopropellant system is that the system flow or pressure can be controlled with a servovalve that meters the liquid monopropellant to a decomposition chamber rather than controlling the hot gas itself. This cannot be done if the system response requirement is too high, because of time lags inherent in the decomposition process.

Although the annular compartment area, which is usually provided for flight control servos, is not compatible with the central gas generator design, a manifolded system will be assumed for reliability. Canard control systems can be located at the bulkhead station, which allows the full compartment space to be used. The resulting short cylindrical

space is ideally suited for a simple gas generator and closely manifolded servoactuator system, without any hot gas tubing. The design concept for such an integrated package is shown in Figure 2.

Sizing the grain

To avoid the interesting—but detailed—studies needed to arrive at the optimum configuration for pressure control and weight, an end-burning or cigarette type of grain is assumed. The grain weight is determined by the possible peak demand on the system at the worst combination of pressure and temperature. The safety margin in weight also depends on the configuration choice.

Initial temperature and chamber pressure have a pronounced effect on grain burning rate; an increase in either will result in a higher burning rate. It is important, therefore, to provide pressure control devices, such as relief valves, which have sufficient capacity to prevent the partial clogging of the passages from allowing the gas generator to "bootstrap" itself into a wasteful expenditure of energy. The grain must be sized to provide the peak demand at the lowest grain temperature, minus 65 deg F, but must be long enough to last for the full flight at relief valve cracking pressure and maximum stabilization temperature, plus 160 deg F.

Gas generator design

Four identically sized, restricted bleed servovalves will be used. These valves in effect present a fixed area flow orifice to the gas generator, simplifying its design considerably. Baffles and filters can then be placed between the gas generator and the servovalves as required. Igniter, safety disc, flow port, and particle screen installation are considerably facilitated by this adoption. The most important feature of this approach is that the gas generator does not note any change in the flow requirements, and the relief valve is only required to function under abnormal conditions. The apparent wastefulness of gas by the servovalve is offset by its simplicity.

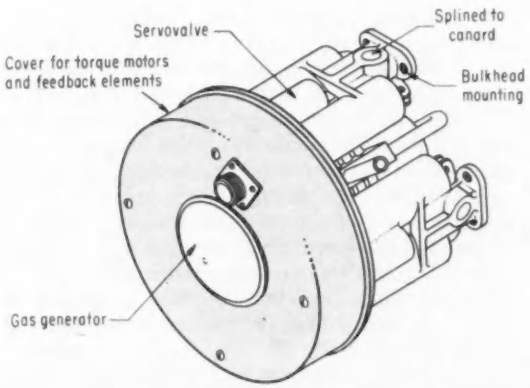


FIG. 2. Integrated servosystem as used in the canard control of Fig. 1.

The long term storage requirement of the system is satisfied if the grain and igniter are hermetically sealed in the chamber in an inert atmosphere. This seal must not be jeopardized during checkout testing of the system with air. To do this without special valving, which would be a reliability problem at launch, the burst diaphragm seal is supported in the reverse flow direction by a multipassaged screen. This also prevents pieces of fractured propellant from passing downstream unburned.

Servomotor design

It is more convenient to use a rectilinear actuator with linkage to produce a limited-angle rotary motion than an airmotor or other rotary device. The seals and bearings are considerably simplified and more reliable. The most satisfactory design for producing this rotary motion in a small package, with minimum sealing problems and without complicating the linkages and bearings, is the push-push actuator shown schematically in Figure 3. This configuration is less sensitive to steady acceleration and vibratory g loadings than is the double-ended design. It also moves the main piston seals out of the hot spot and eliminates two critical rod seals of the double-ended type. The effective piston area is greater for a given piston rod size, resulting in a more compact design. Articulation of the actuator is avoided, without the resulting side loads on the piston rods, if care is taken in contouring the matching rod and yoke surfaces. This design has been evaluated for both hot gas and high temperature pneumatic servos. The Sidewinder was made an extremely simple and reliable missile through the use of a bang-bang version of this basic approach.

The details of construction of the actuator change only slightly with the type of servovalve used, since most servovalves considered for flight systems are ported to receive the hot gas from the actuator manifolding. In the valve design of Figure 3, the hot gas is introduced directly to the actuator pistons through properly sized orifices. The pressure in each actuator volume is controlled by proportional variation in the outlet flow restriction. Since the flow through the fixed and variable restrictors is normally sonic or near sonic, the resulting pressure vs differential current for this type of servovalve is as shown in Figure 4. Note that this is the resulting net pressure producing the output torque. Although not measurable in this small reproduction the hysteresis for such a valve can be kept very low.

The torquemotor driving the controlling element has very low force and fast response. The aerodynamic balancing of the control element used in this valve design keeps side load friction torque at a minimum. With proper flow path design the destabilizing flow torques are not realized.

The open-center servovalve for this application can also be used conveniently in longer duration

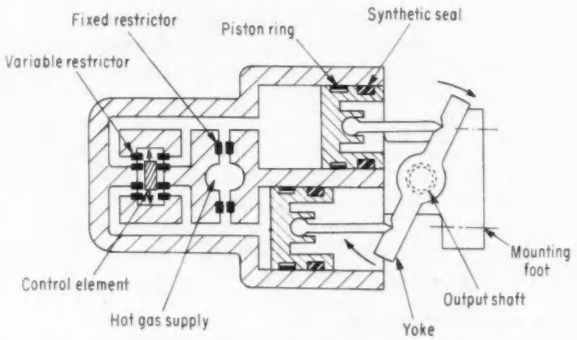


FIG. 3. Servovalve and push-push actuator combination used in package of Fig. 2.

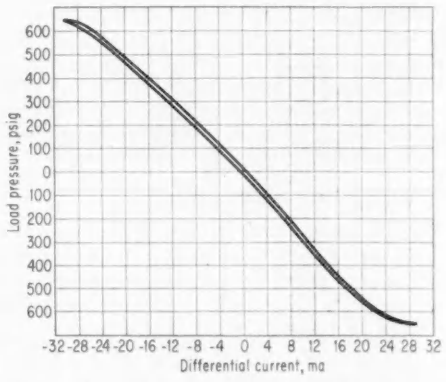


FIG. 4. Low hysteresis of the valve of Fig. 3. Supply pressure for this case is 1,000 psi. Load pressure is the difference between pressure on "clockwise" piston and "counterclockwise" piston.

monopropellant and cold gas systems when reliability or low electrical power consumption is more important than fuel weight. Many other valve designs are possible for hot gas systems, either open center or closed center. Closed-center spool or plate valves, two-stage pressure control valves, pulse-width modulated two-stage flow control valves, and various bistable models used with compensating circuitry have been used successfully with hot but relatively clean gases. Surprisingly, a well engineered single-stage spool-type servovalve has demonstrated considerable reliability in long duration tests with hydrazine byproducts at 1,200 deg F.

The fuel conservation characteristics of a closed-center servovalve are often obtained at the expense of reliability compared with simpler open-center designs. With the turndown ratios presently obtainable with solid propellants, it is not practical to use a closed-center servovalve since this puts the burden of pressure regulation on a full-flow relief device. An open-center valve that has a nearly fixed flow factor and operates over a reasonable variation in chamber pressure can be used with a simple gas generator. Such a design would require only a simple burst disc as an overpressure safety device, or, at worst, a relatively low-flow relief valve for pressure regulation.

Since the hot gas is introduced directly into the actuator through a small fixed orifice when using the restricted bleed design, materials are tailored to the job at hand. The orifice must be a special, abrasion resistant, high temperature alloy, but the material used for the body of the actuator is not as critical. The temperature rise of the body, with such moderate ambient temperatures and short time exposure, is not sufficient to approach the yield point. Hot gas flow past the actuator piston seals could be very damaging from the combined effects of local hot spots, heating of the rotary potentiometer, and the wedging of particles in the close clearance around this piston. The answer to the piston bypass leakage problem lies in a two-stage sealing design. The leakage flow is eliminated by the use of O-ring seals at the outer extremity of the piston, where the actuator is cooler. The lack of flow then makes it possible to protect the synthetic seals themselves by means of a high temperature piston ring combination, which also serves as the bearing surface. This approach makes the clearance less critical and reduces the tendency to gall.

The servovalve body has no high stresses because its bulk is so large compared with the pressurized volumes in the passages. The control orifices and the element positioned by the torquemotor are, therefore, the only components which require special investigation for abrasion resistance, deformation, or scaling under hot gas conditions. The high temperature torquemotor can be isolated from the valve body itself by means of ceramic structural pieces. Hot gas exhaust protection is provided by metallic shielding around the torquemotor, electrical connectors, and feedback elements.

Synthesis of the hot gas servo

The servo designer must now determine servovalve size, type of feedback elements, amplifier gain, and characteristics of the compensating networks to meet the static and dynamic response characteristics under various possible input and load conditions. The gas servosystem with a friction load is complex. The designer cannot simply put its uncompensated forward loop characteristics on the computer, throw in a feedback element or two, and adjust gains to get a satisfactory response. To arrive at a first approximation of the required subsidiary loop compensation, the servo designer must first determine stability, based on an approximate linear analysis. This analysis allows for a certain gain variation, caused by component differences or by operation of the system itself. Friction loading is treated as an input at the torque load summation. Adjustments are made as a result of reevaluation of the linear synthesis procedure, in this case, Bode plot.

COMPENSATING THE HOT GAS SERVO

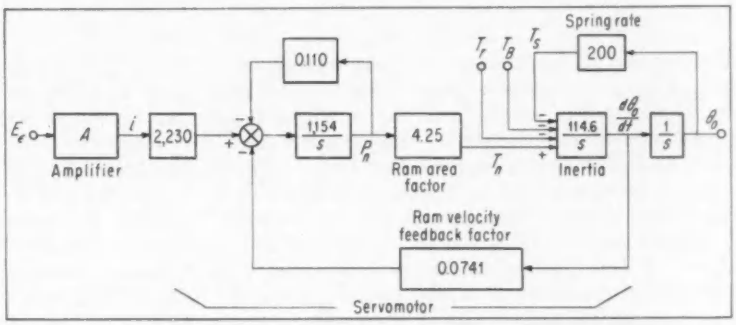


FIG. 5. Functional block diagram of the uncompensated system.

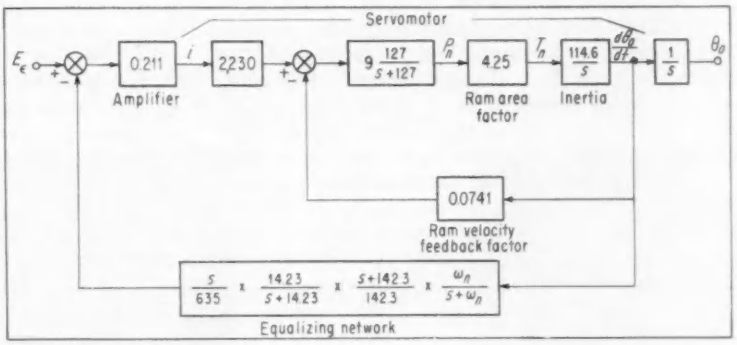


FIG. 6. Functional block diagram of the uncompensated servo with subsidiary feedback added.

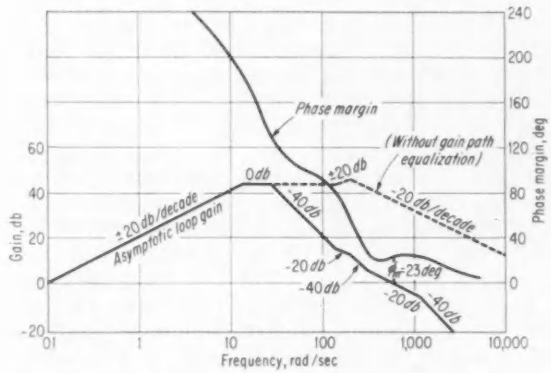


FIG. 7. Response of the subsidiary loop of Fig. 6.

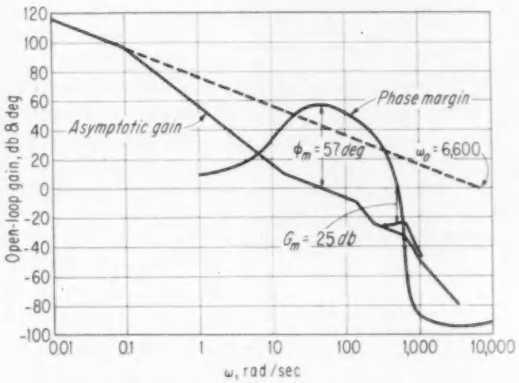


FIG. 8. Response of the over-all servo loop.

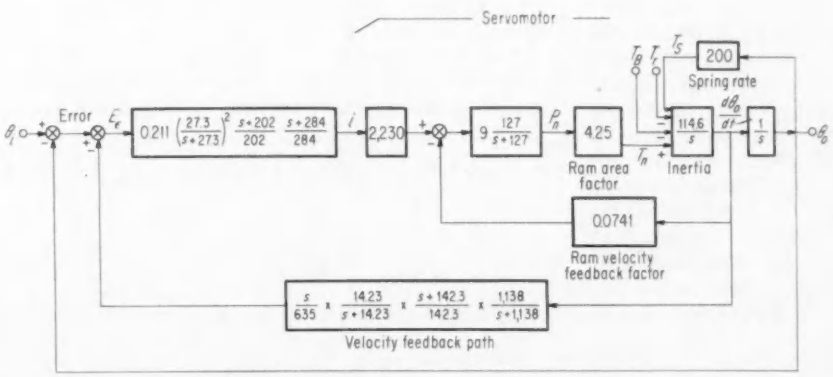


FIG. 9. Functional block diagram of the system with compensation added.

The functional block diagram of the uncompensated hot gas servosystem is shown in Figure 5. The valve characteristics result from the configuration for optimum power output at the required pass band. The ram velocity feedback factor is a characteristic of the valve-actuator combination rather than a transducer signal. Note that any generated velocity feedback used to close the servo loop will only add to the existing feedback factor. Too large a velocity feedback tends to be destabilizing since it drops the damping ratio of the servomotor loop very rapidly. This is experienced in the actual test of a servomotor with only position and velocity feedback.

A preliminary analysis of a dither technique for breakup of the friction shows that proper dither requires a servovalve much faster and of higher flow than that already selected to handle the positioning requirements. A low frequency dither would produce system errors outside the specified limitation if the friction load were not present. Transient pressure feedback proves somewhat impractical because of the small torques to be sensed relative to the total torques for which the sensing system must be designed. A diaphragm or bellows made to withstand high pressure is not going to be very sensitive to low level changes.

Linearized analysis

The minimum (dc amplifier) gain A is determined from the specified resolution sensitivity of 0.35 deg and the maximum expected output torque of 3,100 lb-in. If plus or minus 6 db gain variation is allowed in the gain path for possible temperature effects, wear, variation in components, or variation in the propellant, the allowable error becomes 0.175 deg. From Figure 5 the required amplifier gain can be determined from the stall torque condition:

$$\frac{T_n}{\epsilon}(j0) = \frac{3{,}100}{0.175} \cong 18{,}000 \text{ lb-in./deg} \qquad (1)$$

$$\text{but } \frac{T_n}{\epsilon} = \frac{T_n}{i} \times \frac{i}{\epsilon} \text{ and } \frac{T_n}{i} = 2{,}239 \times 9 \times 4.25 \text{ lb-in./ma} \qquad (2)$$

which gives $A = i/\epsilon = 0.211$ ma per deg.

The resulting system could be equalized to the desired open-loop characteristic if it were not for the effects of friction. Most of the servomotor energy is required to overcome this nonlinear friction load. Therefore the servo bandwidth would vary widely with the amplitude of input signal, compounded by an anticipated variation in friction force magnitude. A subsidiary loop must be incorporated which will nullify the effect of friction and determine the final position loop transfer function. The resulting open-loop transfer function will be the closed-loop transfer function of the subsidiary loop. Since the subsidiary loop must have high loop gain in the neighborhood of the position loop crossover frequency, then the closed-loop transfer function of the subsidiary loop equals the reciprocal of its feedback path transfer function. This feedback path transfer function will largely determine the open position loop transfer function within the servo bandpass. Spring rate seems too variable to be included in the servomotor characteristic.

Since the specification calls for a plus or minus 3-db amplitude response of 10 cps, the crossover frequency must be maintained at about 45 rad per sec. To achieve a minus 20 db per decade slope skirting 45 rad per sec, a plus 20 db per decade slope must be provided over the same band in the subsidiary loop feedback path. This can be produced by a velocity feedback, which, for practical reasons of transducer drift and null, will also have a low frequency washout. A washout properly positioned in frequency will also maximize the acceleration error constant of the over-all system. The washout will provide a minus 40 db per decade slope immediately preceding the minus 20-db slope at crossover. Since the uncompensated gain path has a pole at the origin and a quadratic factor of approximately 200 rad per sec break frequency, it will be falling at 60 db per decade above this frequency. Pure velocity feedback without compensation in either the subsidiary feedback path or in the gain path will produce an unstable system because the phase margin will be critical in this area. To compensate for this, a lead network must be placed in either the gain path or in the subsidiary feedback path. However, placement of the lead in the gain path will not allow the amplitude response of the over-all loop to fall rapidly enough above crossover to attenuate the system sufficiently for minimum response to extraneous load and input disturbance. The minus 20 db per decade slope will extend from zero db at 45 rad per sec through 30 cps or 188 rad per sec. The amplitude response would then be down only 20 $\times$ log (188/45) or 12.5 db at 30 cps, rather than the required minus 15 db. The lead must therefore be placed in the subsidiary path, providing a minus 40 db per decade slope for the over-all position loop starting somewhere above crossover. If a decade is allowed to skirt crossover with a minus 20 db per decade slope, the velocity feedback washout extends from 0 to 14.2 rad per sec; the lead begins at 142 rad per sec and extends to some high frequency outside the band of interest.

Figure 6 is the functional block diagram of the uncompensated gain path and subsidiary feedback path. The expression for the subsidiary loop is:

$$\mu\beta_s(s) = 9.4s \frac{14.23}{(s+14.23)} \times \frac{(s+142.3)}{142.3} \times \frac{1}{\left(\frac{s^2}{202} + \frac{2 \times 0.315}{202}s + 1\right)} \times \frac{\omega_n}{(s+\omega_n)} \qquad (3)$$

The corner frequency ω_n has not yet been deter-

mined. Neglecting this, the dotted curve of Figure 7 shows that the bandwidth of the subsidiary loop extends well above 10,000 rad per sec. This is not realistic, since torquemotor and amplifier lags plus lead termination would cause excessive phase lag in the subsidiary loop. Equalization of the gain path is necessary to limit bandwidth of the subsidiary loop. The cutoff frequency for this loop is chosen as 569 rad per sec, four times the minus 20 db to minus 40 db position loop break frequency.

The compensated subsidiary loop gain and phase curves of Figure 7 show the lead termination chosen as 1,138 rad per sec, approximately twice the subsidiary loop cutoff frequency. To satisfy the cutoff frequency selected for this loop, two finite lag networks of 27.3 rad per sec of the servomotor loop and a lead network of 284 rad per sec corner frequency have been added to the electronic amplifier, leaving its transfer function as

$$\frac{i}{E_\epsilon}(s) = 0.211\left(\frac{27.3}{s+27.3}\right)^2 \times \frac{s+202}{202} \times \frac{s+284}{284} \qquad (4)$$

The open position loop transfer function equals the closed-loop transfer function of the subsidiary loop. Solving for this, using the expression $\mu/(1+\mu\beta_s)$, is a fairly lengthy procedure if care is taken to explore the phase relationships in the area of subsidiary loop crossovers. Figure 8 shows the resulting open-loop gain and phase relationships. More than adequate phase and gain are indicated for this linear approximation of the hot gas servosystem.

The velocity error constant for the system is 6,600 sec^{-1}. Since the first break frequency of the open-loop transfer function occurs at 0.096 rad per sec, the acceleration constant is the product of these two: 633 sec^{-2}.

SIMULATING THE HOT GAS SERVO

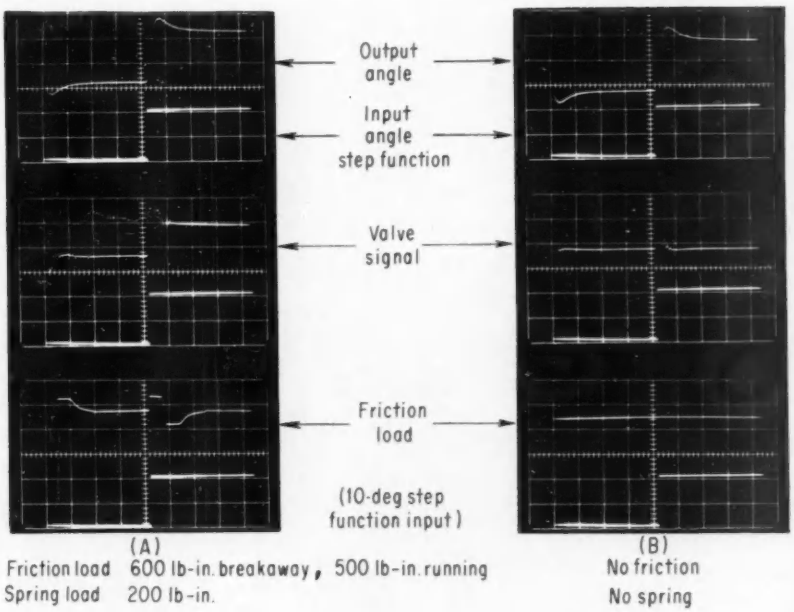


FIG. 11. Step change response of the computer simulated system.

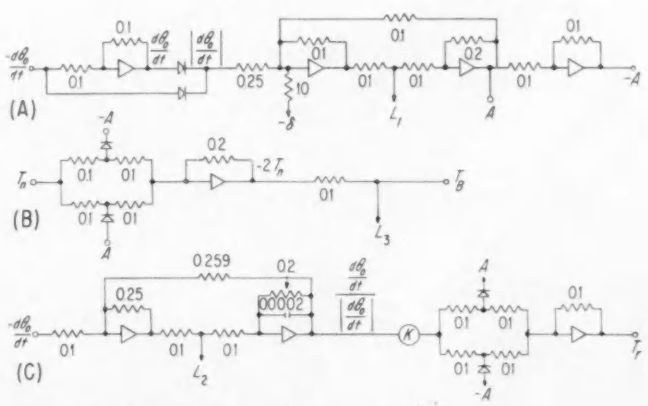
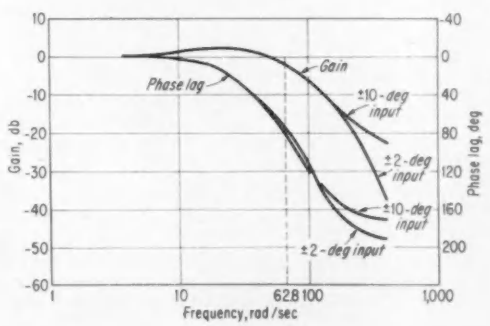


FIG. 10. Analog computer circuitry simulates friction.

FIG. 12. Frequency response of the simulated system for the following load conditions: inertia, 0.5 lb-in.-sec^2; breakaway friction, 600 lb-in.; running friction, 500 lb-in.; spring rate, 200 lb-in./deg.



Studying the system by computer

The linearized system synthesis is substantiated in the presence of friction and spring rate by conducting an analog computer investigation. The functional block diagram of the hot gas servosystem is shown in Figure 9. In this case the spring rate is presented at its maximum value, although it is allowed to become negative for a complete investigation. The torque inputs represent friction torques satisfying the requirements of coulomb and breakaway friction. The equations for these loads are:

Breakaway friction torque

$$T_B = T_n \text{ for } \left|\frac{d\theta_o}{dt}\right| < \delta \qquad \text{and } |T_n| < |T_B|_{\max} \tag{5}$$

$$T_B = T_{B\max} \text{ for } \left|\frac{d\theta_o}{dt}\right| < \delta \text{ and } |T_n| > |T_B|_{\max} \tag{6}$$

$$T_B = 0 \text{ for } \left|\frac{d\theta_o}{dt}\right| > \delta \tag{7}$$

Running friction torque

$$T_n = 0 \text{ for } \left|\frac{d\theta_o}{dt}\right| < \delta \tag{8}$$

$$T_n = T_r \frac{\frac{d\theta_o}{dt}}{\left|\frac{d\theta_o}{dt}\right|} \text{ for } \left|\frac{d\theta_o}{dt}\right| > \delta \tag{9}$$

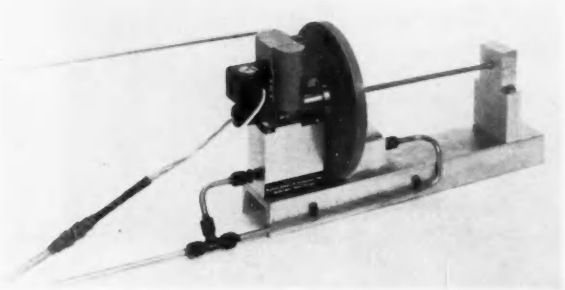


FIG. 13. A breadboard model of the servomotor under test.

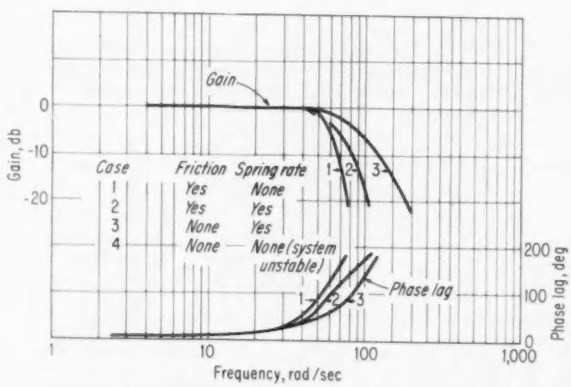


FIG. 14. Results for the breadboard system test, with displacement feedback only and the conditions of Fig. 12, but no breakaway friction and signal input of plus or minus 2 deg.

where T_n is the servomotor output torque, $d\theta_o/dt$ is the output angular velocity, and δ is a small angular velocity.

The circuit of Figure 10A shows the method used to determine when $|d\theta_o/dt| > \delta$. The $|d\theta_o/dt|$ output of the first two amplifiers and their output diodes is compared with δ and the difference used to energize the bistable flip-flop circuit. A loop gain of plus 1 insures true backlash-free, Schmitt-trigger action; limiter L_1 prevents overload in this circuit and also sets the magnitude of A. The action of the circuit is such that A is plus 80 volts when $|d\theta_o/dt| > \delta$, and A is minus 80 volts when $|d\theta_o/dt| < \delta$. The A and minus A signals are used to block T_B and T_r at the proper time.

The next circuit, Figure 10B, generates the breakaway friction. Here T_n reaches the amplifier only when A = minus 80 volts, and minus A = plus 80 volts and the blocking diodes are open. The limiter L_3 restricts the breakaway friction torque.

The circuit of Figure 10C generates running friction. The first two amplifiers in flip-flop configuration generate a voltage whose level is set by limiter L_2 and whose sign indicates the direction of rotation of θ_o. The action of the diodes is identical to that of the circuit for breakaway friction except that the voltage reaches the amplifier when $|d\theta_o/dt| > \delta$. The potentiometer sets T_r in the output.

The transient responses to step change inputs in Figure 11 typify those obtained for various load conditions and for inputs of 2-10 deg amplitude. Since there is little difference in the response under stipulated maximum load and zero load conditions, the system seems to be quite satisfactory. The frequency response data, Figure 12, show the slight effect of increased input amplitude. Gain and phase curves for each are just within specification.

Testing an actual system

An uncompensated breadboard servosystem with a friction, spring, and inertia load rig was tested to confirm its closed-loop response characteristics. The servomotor, Figure 13, is of the type designed for the package described by Figure 2. Test results for maximum and zero load conditions, Figure 14, show the need for further compensation. These results agree very closely with the computer responses. Note that phase lag becomes a more critical aspect of performance than anticipated.

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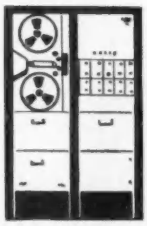

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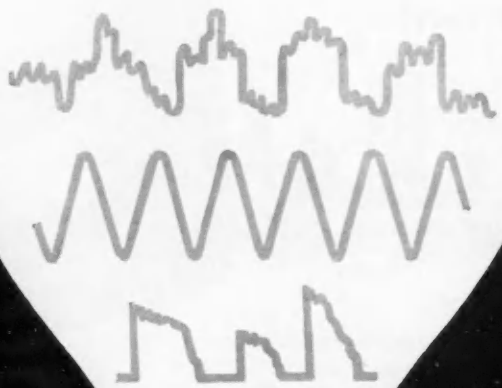

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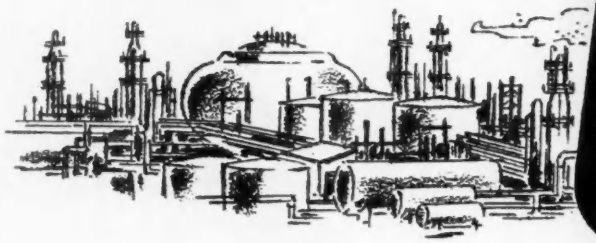

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CONTROL VALVES

first cost vs operating cost

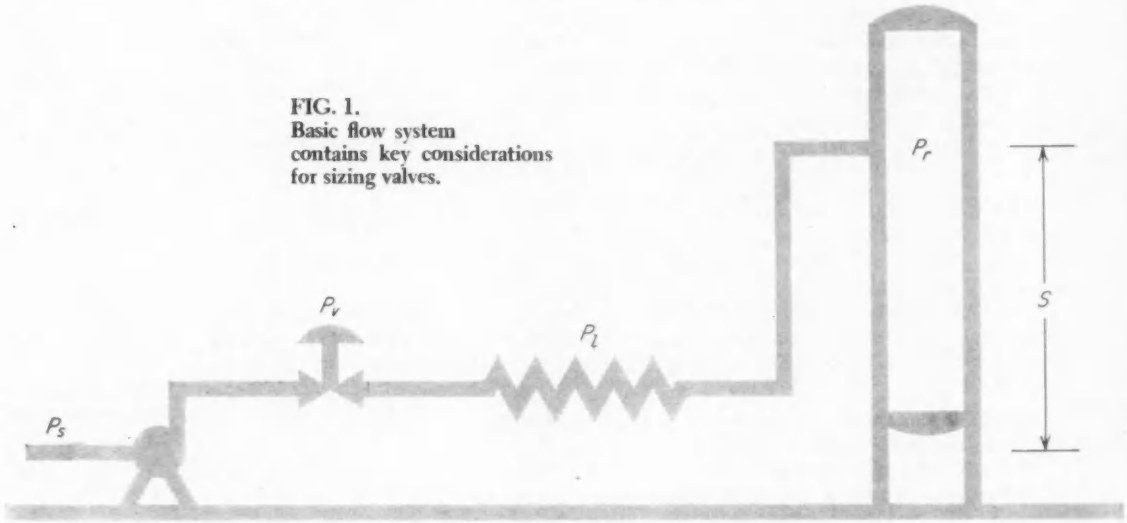


FIG. 1.
Basic flow system contains key considerations for sizing valves.

WILLIAM J. SCHMIDT
Stone & Webster Engineering Corp.

THE GIST: Pumping a fluid through a valve costs money. Present methods of valve sizing do not take this into account. Hence the author argues that control valve sizing should be based on smallest annual operating cost, not smallest first cost, provided of course that the selected valve gives good control. A numerical example comparing the economic and conventional methods of valve sizing is given.

The valve size selected for a particular flow control application should rightly depend on the valve's annual operating cost. One key factor in the operating cost is the cost of pumping a fluid through the valve; another is the initial cost of the valve. The annual cost minimization method presented here permits valve sizing in terms of C_v, and hence nearest line size, by taking into account pumping cost, initial cost, and such other considerations as normal and maximum flowrate, system pressure loss, expected life, and interest rate. The valve size determined in this manner, when compared with valve size determined by a conventional sizing method, gives the control engineer one more set of facts on which to base his final decision.

The flow system in Figure 1 takes into account the many factors involved in sizing control valves. Here, P_s is the suction pressure, P_r the receiver pressure, S the static head, P_l the equipment friction loss (piping, heat exchangers, etc.), and P_v the control valve drop. Thus, the differential pumping head H supplied by the pump at any system flow is

$$H = S + P_v + P_l + (P_r - P_s)$$

Assuming constant suction and receiver pressure with changing flow, the only terms whose values can be varied during design are P_v and P_l, since S and $(P_r - P_s)$ are set by process requirements and equipment configuration. Furthermore, the equipment and line drop P_l is presumably set at a value

that yields the most economic line or heat exchanger size. Therefore, the control valve drop P_v remains the only friction loss to be determined.

The value of P_v is ultimately determined by the control valve size. A large P_v is required for a small valve and a small P_v for a large valve. Thus, since a choice exists in using valves over a range of sizes, each with a correspondingly different pressure drop, some economic combination of initial valve cost and annual pumping cost to provide P_v can be made.

The annual cost K of any piece of equipment, including control valves, is

$$K = (C - L)\left[\frac{(1+i)^m}{(1+i)^m - 1}\right] + Li + Y \qquad (1)$$

where C is the initial investment, L the salvage value, i the interest rate, m the number of useful years, and Y the annual operating expense. For control valves the salvage value L is assumed zero and Y is actually the annual power cost P of pumping the liquid *through the control valve*. For simplicity, then, the valve's annual cost becomes

$$K = R\,(F + 1)\,C + P \qquad (2)$$

where R, the capital recovery cost, is the bracketed expression in Equation 1 and F is the decimal fraction cost of installing the valve.

By using Equation 2, a valve size having a minimum annual cost can be determined in terms of C_v, provided that C and P are also expressed in terms of C_v. This is the general method for obtaining the economic valve size, but an example is given here by adopting specific values for R, F, and specific functions of C_v for C and P.

• Initial cost, $C(C_v)$

A study in June 1959 of the cost of carbon steel, equal percentage, V-port, double-seated valves, 1 to 12 in. in size, from six manufacturers indicated that the average cost in terms of C_v is

$$C = 60.2\,C_v^{0.374} + 2.41\,C_v^{0.732} + 0.0340\,C_v^{1.492}$$

Here, the cost includes a valve positioner for valves 4 in. and larger.

• Power Cost, $P(C_v)$

Power cost is obtained from

$$P = aF_n\,P_v \qquad (3)$$

where, from Reference 1,

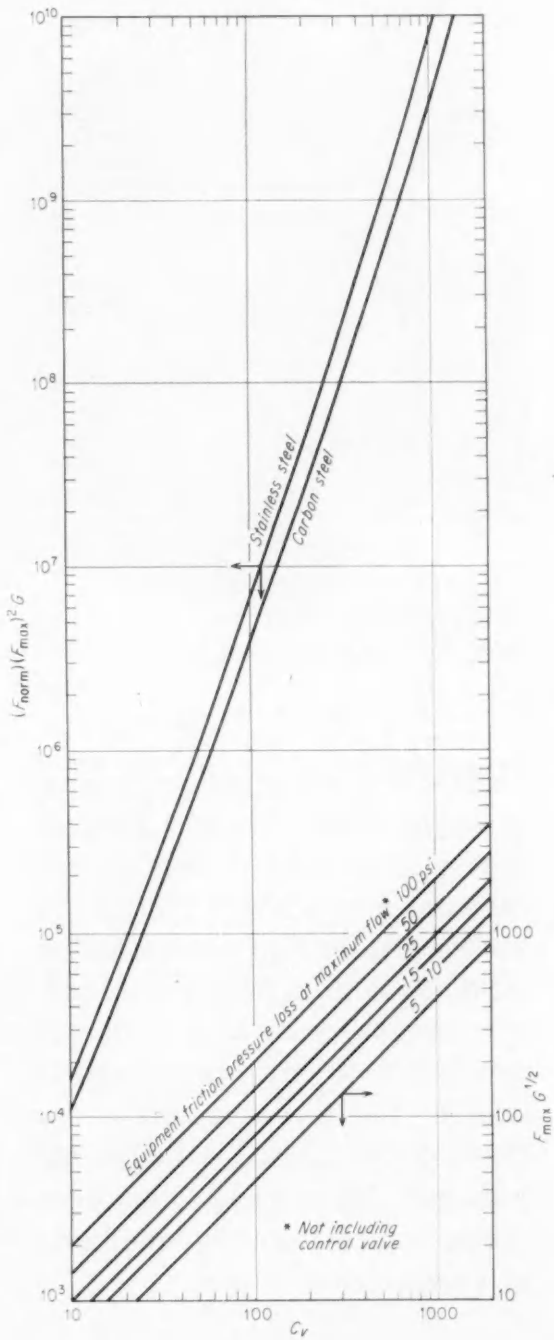
$$P_v = P_t N^2 + P_t N^2\,(C_t/C_v)^2 - P_t \qquad (4)$$

$N = F_{max}/F_{norm}$ and a is a constant involving power cost per gpm per psi. Here, for given flow conditions, the only variable is C_v.

The power cost equation does not have to take into account the head vs capacity characteristic of centrifugal pumps. For a given pump, many different characteristic curves using different impeller diameters, each parallel to the other, are available. It can be shown for two different valves for which two different impeller sizes would be required that the additional head at flows less than maximum is

ECONOMIC VALVE SELECTION CHART

FIG. 2. Upper set of curves permits selection of valve with smallest annual operating cost, as based on factors described in text. Lower set of curves permits selection of valve based on equal percentage valve characteristic equivalent to $C_v/C_t = 5$, see Figure 3.



exactly the same for both impellers and therefore does not affect the economic selection of the valve. However, the centrifugal pump's characteristic may affect valve controllability, Ref. 2.

Minimizing annual cost

Now that C and P have been stated in terms of C_v, these factors are inserted into Equation 2, giving

$$K = R\,(F+1)\,[60.2C_v^{0.324} + 2.41C_v^{0.732} + 0.0340C_v^{1.492}] + aF_nP_v \quad (5)$$

Equation 5 is then differentiated and the derivative dK/dC_v is set equal to zero to determine the value of C_v that will give the minimum annual cost. The mathematical manipulations are not shown. The result is

$$C_v^3\,[22.5C_v^{-0.626} + 1.765C_v^{-0.268} + 0.051C_v^{0.492}] = \frac{2a}{R\,(F+1)}\,F_nF_m^2G \quad (6)$$

The installation cost F is assumed to be 15 percent of the initial valve cost. The capital recovery factor R is 0.149, based on $m = 10$ years of useful life and an interest rate i of 8 percent. The factor a used here is determined as follows:

$$\text{Total hp} = \frac{F_nP_v}{(1{,}714)\,(E_p)\,(E_m)}$$

where the pump efficiency E_p is 0.75 and the motor efficiency E_m is 0.90. The total horsepower in terms of equivalent kilowatts is then:

$$\text{kw} = \frac{0.746\,F_nP_v}{(1{,}714)\,(0.75)\,(0.90)} = 0.648 \times 10^{-3}F_nP_v$$

Assuming a 90 percent plant utilization factor (7,920 hrs per yr) and a power cost of $0.01 per kwhr, the annual power cost per gpm per psi is

$$a = 5.1 \times 10^{-2}$$

By combining these values,

$$\frac{2a}{R\,(F+1)} = \frac{2 \times 5.1 \times 10^{-2}}{0.149 \times 1.15} = 0.595$$

For a given value of C_v, the left side of Equation 6 is divided by 0.595 so that a curve of $F_nF_m^2G$ vs C_v for carbon steel valves can be plotted, Figure 2. (The figure also contains a similar plot for stainless steel control valves.) Thus the economic valve size, C_{ve}, depends only on the normal and maximum system flows.

In practice, one cannot purchase a valve having exactly the C_v value determined from the curve. Manufacturers rate their valves in line sizes and specify C_v ratings for each size. Thus, it is necessary to select a valve size having a C_v rating as close to the computed C_{ve} as possible.

Control considerations

The role of the valve is to control flow. A valve selected as the most economical in terms of lowest annual cost must be checked to see if it will adequately regulate flow over the required flow range. This is done by comparing the economically sized valve against a valve sized by a conventional method.

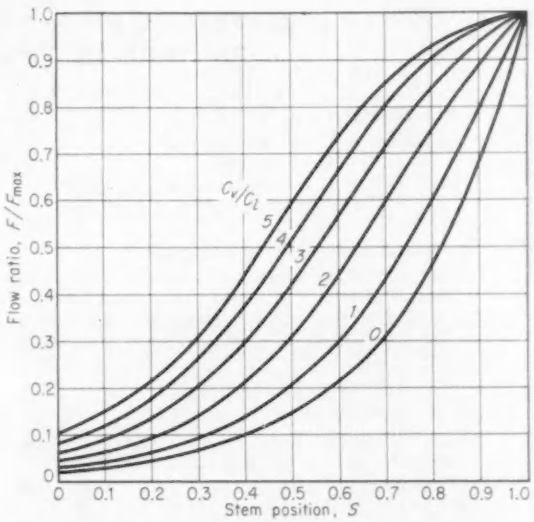


FIG. 3. Equal percentage valve characteristic becomes fairly linear as equipment friction loss increases.

From a control standpoint, the ideal flow vs valve stem position characteristic should be linear, since at any stem position the derivative d(flow)/d(lift) is constant. That is, the valve gain is constant, which means that one setting of the controller's proportional band offers good, stable control over a wide range of operating flows.

Valstar (Ref. 1) and others have shown that the nonlinear characteristic of an equal-percentage valve shifts to a linear characteristic when the associated pipe and equipment friction losses, in terms of C_l, are taken into account. Figure 3 contains five characteristic curves, where

C_v/C_l	$(P_v/P_l)_m$
0	0.0
1	1.0
2	0.250
3	0.111
4	0.063
5	0.040

Here, a C_v/C_l ratio of 2 means that the valve takes 25 percent of the other friction losses in the system at maximum flow.

A study of the curves in Figure 3 leads to the conclusion that a substantially linear characteristic over most of the flow range can be obtained with C_v/C_l ratios between about 1.5 and 5. The designer has the option of selecting valves that absorb between about 50 percent to 4 percent of the other system losses. Hence, from the viewpoint of control it is difficult to justify the rule-of-thumb criterion that the valve should absorb between 20 and 50 percent of the other friction losses. This rule may be too restrictive because valves having pressure drops of about 5 to 10 percent may offer good

COMPARING ECONOMIC AND CONVENTIONAL METHODS OF CONTROL VALVE SIZING.

• A NUMERICAL EXAMPLE

Given $F_n = 1{,}000$ gpm
$F_m = 1{,}500$ gpm
$(P_l)_m = 50$ psi drop at 1,500 gpm
$(P_l)_n = 22.2$ psi drop at 1,000 gpm
$G = 1$

Material of construction: stainless steel

Therefore, $F_n F_m^2 G = 1{,}000 \times 1{,}500^2 \times 1 = 2.25 \times 10^9$

From Figure 2, $C_{vc} = 680$. One maker's catalog shows that a valve with a C_v rating of 640, the closest to 680, is sized at 8 in. In stainless steel it costs $2,820.

Calculate the corresponding C_{vc}/C_l:

$$C_l = 1{,}500/50^{1/2} = 212$$
$$C_v/C_l = 640/212 = 3.0$$

From Figure 2, at $F_m G^{1/2}$, C_{vc} is 1,070. Thus the economic valve size C_{vc} yields a C_v/C_l ratio less than 5, meeting the previously proposed control criterion. Suppose the designer decides that $C_v/C_l = 2$ will give adequate control. Then $C_{vc} = 2 \times 212 = 424$. From the same maker's catalog, the nearest valve has a rating of $C_v = 360$, a 6-in. valve costing $2,090. Using this valve, C_{vc}/C_l is $360/212 = 1.7$.

Inspection of Figure 3 shows that the 8-in. valve, with a ratio of 3, gives a better linear characteristic than the 6-in. valve with a ratio of 1.7. In practice, they might be considered to offer equal control. On a first cost basis, however, the smaller valve is preferred. But it is still necessary to calculate which valve has the lower annual cost.

Calculate the pressure drop across each valve at maximum flow:

$(P_v)_m = (P_l)_m/(C_v/C_l)^2$
$= 50/3.0^2 = 5.5$ psi Economic method
$= 50/1.7^2 = 17.2$ psi Conventional method

The total friction heads at F_m required for these two valves are:

Economic $50 + 5.5 = 55.5$ psi
Conventional $50 + 17.2 = 67.2$ psi

At normal flow of 1,000 gpm, $(P_l)_n = 22.2$ psi. Therefore the pressure drops across the valves are:

Economic $55.5 - 22.2 = 33.3$ psi
Conventional $67.2 - 22.2 = 45.0$ psi

The annual cost of the two valves can now be determined from Equation 5 in the text:

8-in. valve, economic method

$K = R\,(F + 1)\,C + aF_n\,P_v$
$= (0.149)\,(1.15)\,(2{,}820) + (0.051)\,(1{,}000)\,(33.3)$
$= 484 + 1{,}700$
$= \$2{,}184$ per year

6-in. valve, conventional method

$K = (0.149)\,(1.15)\,(2{,}090) + (0.051)\,(1{,}000)\,(45.0)$
$= 377 + 2{,}300$
$= \$2{,}677$ per year

Thus, for this particular case, the net saving in using the larger valve is:

Saving per year = $2,677 − $2,184 = $493

While the larger valve costs more initially, there is a saving in pumping cost of $600 per year by using it.

The economic method to determine valve sizing may offer a way of saving money in process operation and control. Whether or not it does depends on such considerations as the capital recovery factor, involving useful life and interest rates applicable to a particular industry or company, the C_v vs the line size of valves, which may vary considerably from one maker to another, and the pump head characteristic.

control and do so at smaller annual cost.

As the valve drop to line drop ratio decreases, excessive distortion of the valve characteristic occurs, resulting in a valve acting more like an on-off than a modulating control valve. It is suggested that for good control the C_v/C_l ratio should not exceed 5. Thus, the maximum suggested C_{vc} for a control valve can be obtained from

$$C_{vc} = 5C_l = 5F_m G^{1/2}/(P_l)_m^{1/2}$$

The lower family of curves in Figure 2, a graphical representation of the equation above, shows C_{vc} as a function of $F_m G^{\frac{1}{2}}$, with equipment friction loss at maximum flow as a parameter. Similar families of curves can be drawn for C_{vc}/C_l ratios of 2, 3, and 4 with little trouble, giving the control engineer a quick comparison of C_{ve}, the economically sized valve, selected on the basis of the upper set of curves in Figure 2, and C_{vc}, the conventionally sized valve, selected for a given control characteristic on the basis of a set of curves like the lower one shown in Figure 2.

In practice, then, the control engineer calculates the valve size C_{ve} based on economics and the valve size C_{vc} based on control.

The economic valve certainly does not imply a smaller valve, compared with a valve sized solely on control, but the usually larger economic valve may often give equivalent control at a smaller annual operating cost. The economic analysis is another factor in making a final decision of valve size.

A specific example, using the stated values and actual valve costs, is worked out in the box above to show the complete procedure for selecting an economically sized valve. The procedure may be further refined by considering the effect of pump head characteristic on control (Ref. 2).

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2. *SOLVING FLOW CONTROL PROBLEMS GRAPHICALLY*, G. A. Martin, "Control Engineering", December 1957, pp. 71-75.

DATA FILE 48

Loaded Parallel-T RC Filters— finding their response graphically

CHARLES T. STELZRIED, Jet Propulsion Laboratory

Parallel-T *RC* filter networks are useful for suppressing unwanted signals or for altering the frequency response of amplifiers, power supplies, oscillators, and control systems. While graphical solutions for the response of unloaded parallel-T *RC* filters have been available for some time (Refs. 1 and 2), the first complete graphical solutions are presented here for the attenuation and phase shift of such networks, subject to the practical problems of finite source and load impedances.

The nodal circuit equations for the loaded filter, Figure 1, are:

$$\frac{e_1 - e_i}{K_1 R} + (e_1 - e_2)\,Cs + \frac{e_1 + e_3}{2R} = 0 \qquad (1)$$

$$(e_2 - e_1)\,Cs + (e_2 - e_o)\,Cs + \frac{e_2}{R} = 0 \qquad (2)$$

$$\frac{e_3 - e_1}{2R} + \frac{e_3 - e_o}{2R} + 2e_3\,Cs = 0 \qquad (3)$$

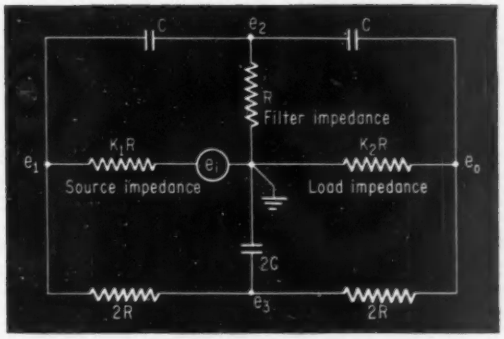

FIG. 1. Loaded parallel-T RC network.

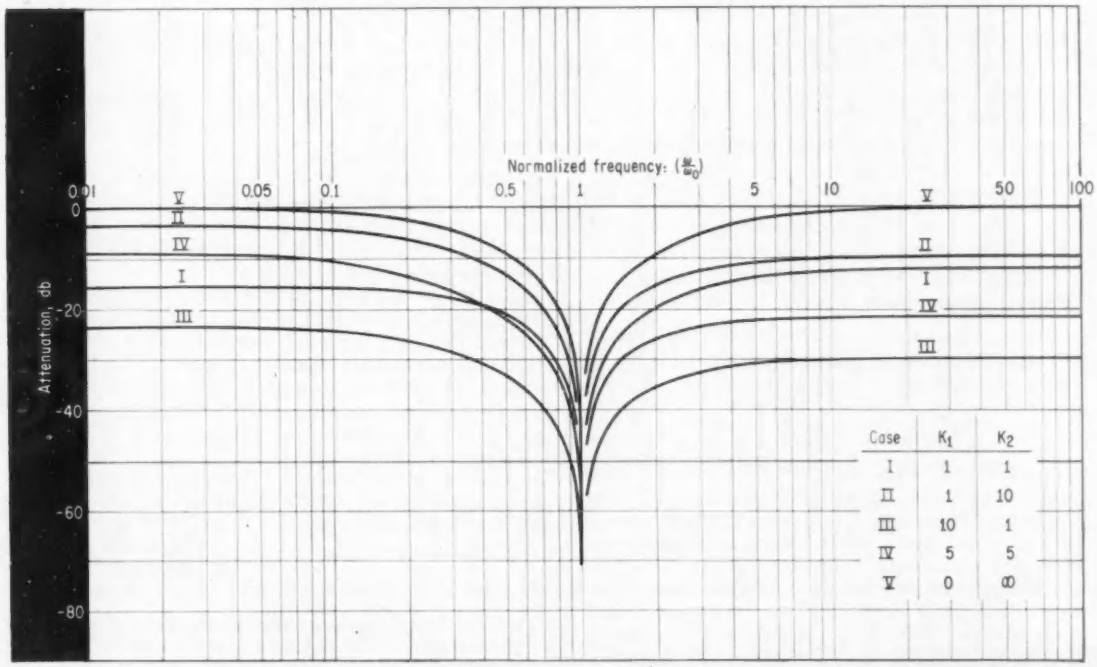

FIG. 2. Attenuation of loaded parallel-T RC filter.

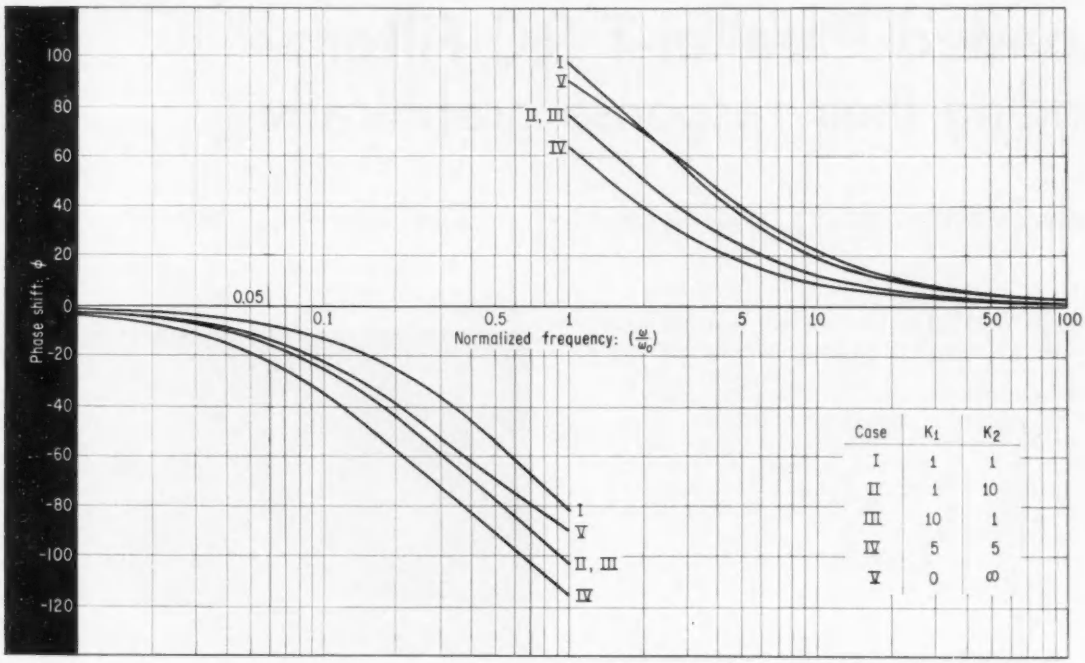

FIG. 3. Phase shift of loaded parallel-T RC filter.

$$(e_o - e_2)\,Cs + \frac{e_o - e_3}{2R} + \frac{e_o}{K_2 R} = 0 \qquad (4)$$

Solving these for the magnitude ratio of voltage response gives

$$\left|\frac{e_o}{e_i}\right| = K_2\left[1 - \left(\frac{\omega}{\omega_o}\right)^2\right]\left\{\left(\frac{\omega}{\omega_o}\right)^4 (2K_1K_2 + K_1 + K_2)^2 + \left(\frac{\omega}{\omega_o}\right)^2\left[(4 + 2K_1K_2 + 4K_2 + 4K_1)^2 + 2\,(4 + K_2 + K_1)\,(2K_1K_2 + K_2 + K_1)\right] + (4 + K_2 + K_1)\right\}^{-1/2} \qquad (5)$$

where $2RC = \dfrac{1}{\omega_o}$ and $s = j\omega$

Finding attenuation

Figure 2, a plot of Equation 5, shows that the attenuation approaches infinity at $\omega/\omega_o = 1$ for all combination values of K_1 and K_2, but that the best filter action, Case V, is obtained when K_1 is as small as possible and K_2 is as large as possible.

As an example of the use of this graph, suppose a parallel-T RC filter with $R = 10$ kilohms is to reject 60-cps hum in a 1,200-cps control system amplifier. If the filter is connected between a 10-kilohm source and a 100-kilohm load (typical vacuum tube output and input impedances), the graph can be easily used to find the attenuation. Since the source impedance equals the filter resistance R and the load equals 10R, $K_1 = 1$ and $K_2 = 10$ so Case II applies. Using $\omega/\omega_o = 1{,}200/60 = 20$, Figure 2 gives the attenuation as 10 db.

Finding phase shift

The phase shift ϕ for the network can be found from Equation 5 to be the negative of the angle whose tangent is

$$\frac{\left(\frac{\omega}{\omega_o}\right)(4+2K_1K_2+4K_2+4K_1)\Big/\left[1-\left(\frac{\omega}{\omega_o}\right)^2\right]}{\left[(4+K_1+K_2)-(2K_1K_2+K_2+K_1)\left(\frac{\omega}{\omega_o}\right)^2\right]\Big/\left[1-\left(\frac{\omega}{\omega_o}\right)^2\right]}$$

This relationship is plotted in Figure 3 for the same values of load and source impedance used in Figure 2. Note that the phase shift jumps 180 deg for all cases at $\omega/\omega_o = 1$. For the amplifier filter given above (Case II and $\omega/\omega_o = 20$) the corresponding phase shift is 6 deg as found from Figure 3.

As another example, consider an amplifier employing a parallel-T RC filter to reject 1,000 cps. The filter, with $R = 1$ kilohm, is inserted between source and load impedances equal to 1 kilohm. Find the operating frequencies at which the phase shift will be less than 10 deg. Since R equals the source and load impedances, $K_1 = K_2 = 1$ and Case I applies. Figure 3 shows that the phase shift through the filter will be less than 10 deg when the operating frequency is greater than $20 \times 1{,}000 = 20{,}000$ cps or less than $0.075 \times 1{,}000 = 75$ cps.

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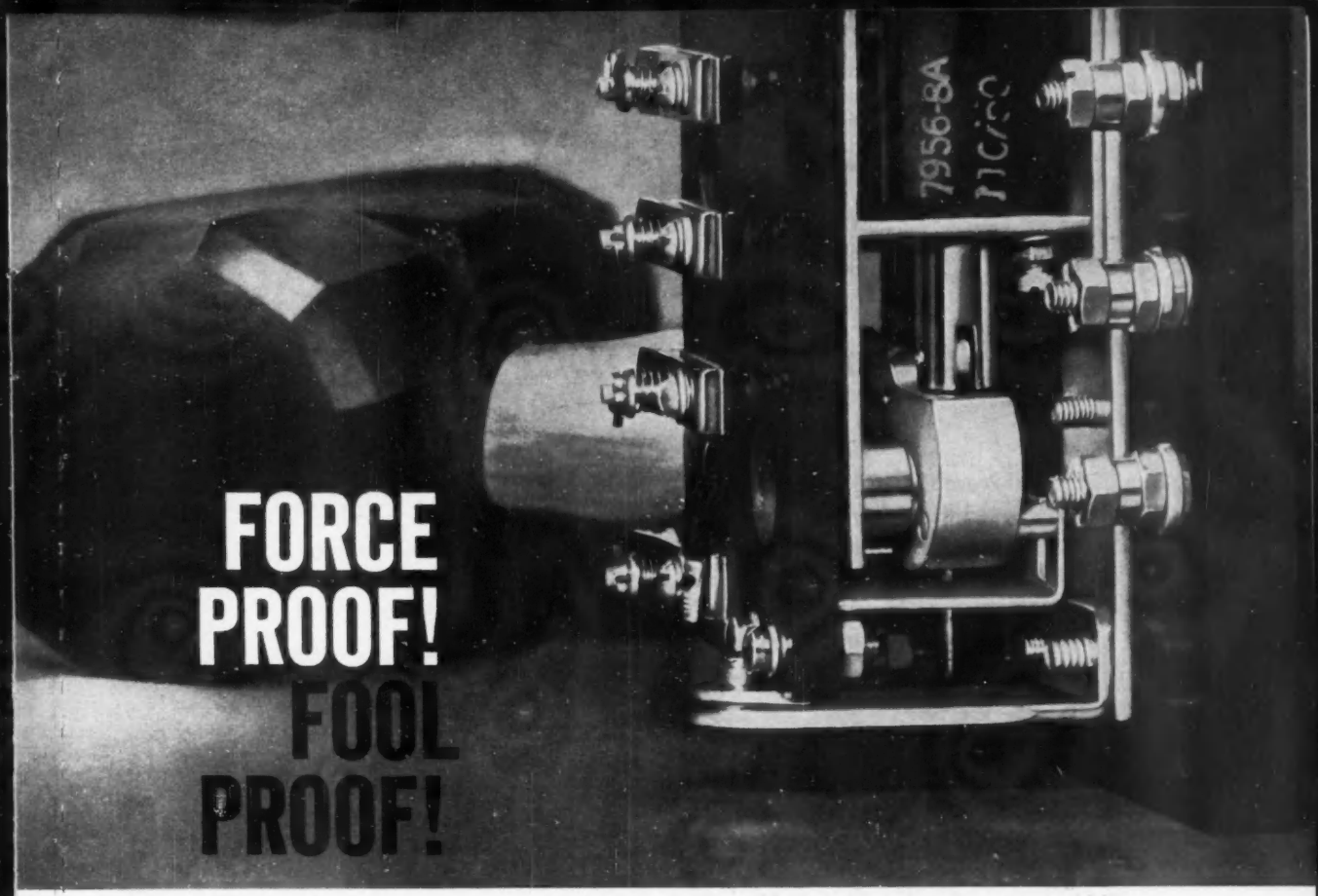

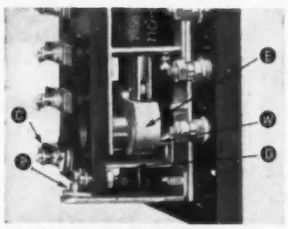

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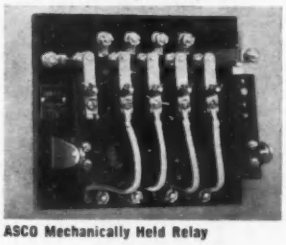

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Part V:

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S. M. BAILEY
Vitro Corp. of America

The stepper motor is an incremental control device. It responds to input pulses by rotating its output shaft in equal angular increments, one increment for each input pulse. Where two or more steppers are remotely located yet must be maintained in perfect stepping synchronism at all times, interlocking circuitry insures that stepper A cannot take a step unless stepper B takes, or has taken, a corresponding step. This applies to either automatic or controlled stepping.

In ordinary control sequences, steppers A and B can be simultaneously pulsed and normally each can be relied upon to take corresponding steps. Interlocks such as discussed here become necessary, however, in those special cases where extremely reliable synchronism is mandatory, as when expensive equipment might be destroyed if a misstep should occur. Applications employing interlocked steppers are ballistic missile prelaunching exercises, reconnaissance drone control, and precise positioning of radioactive fuel elements during processing.

Each interlocked stepper may perform a special electromechanical computing or control function by virtue of the particular device attached to its output shaft. Examples of such devices include functional potentiometers, multi-turn linear potentiometers, control transformers, resolvers, mechanical differentials, rotary-to-rectilinear converters, commutators, and binary encoding data wheels.

Figure 1A illustrates elementary stepper operation. The 1p3t switch energizes either the clockwise coil A or counterclockwise coil A′. After the switch has been held in one position for a least 8-10 millisec, the armature is down and the step has been taken. When the switch is released, the armature returns by spring action to its normally up position.

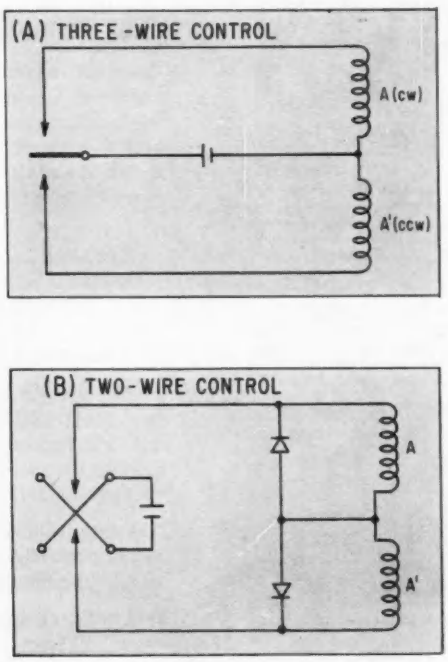


FIG. 1. BASIC STEPPER OPERATION.

Figure 1B shows how diodes across the coils reduce the number of wires between stepper and control point. This arrangement is very useful for interlocked steppers at remote locations.

Interlocked automatic stepping

When remotely located steppers *A* and *B* are simultaneously pulsed as in Figure 2, they will, under normal conditions, each take the same number of steps and their output angles will be equal. With this arrangement, however, steppers may sometimes get out of step. For example, if the cables joining the control and field station are temporarily disconnected for any reason, synchronism may be disturbed. In such cases it may be desirable to introduce absolute interlocks. To have a misstep *prevent* any further stepping, contacts may be placed in both the up and down positions of the respective armatures of the cw and ccw coils so as to fully monitor armature motion.

Figure 3 shows such a basic interlock circuit. (The diodes across each coil make the steppers polarity sensitive, thus reducing the number of control wires between stations.) Stepper *A* at the remote station and stepper *B* at the master station

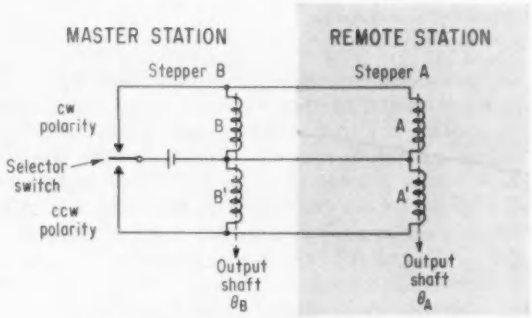


FIG. 2. NONINTERLOCKED STEPPERS.

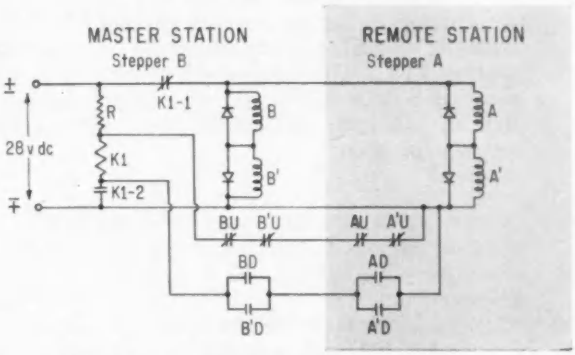


FIG. 3. INTERLOCKED STEPPERS.

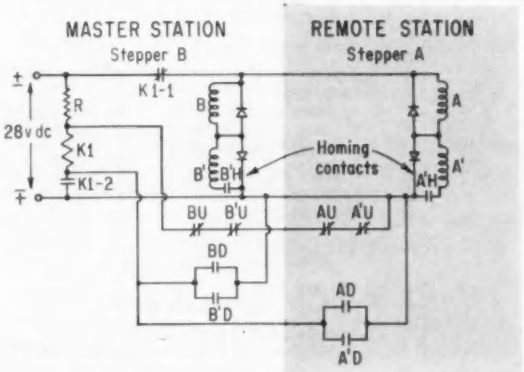


FIG. 4. HOMING INTERLOCKED STEPPERS INDEPENDENTLY.

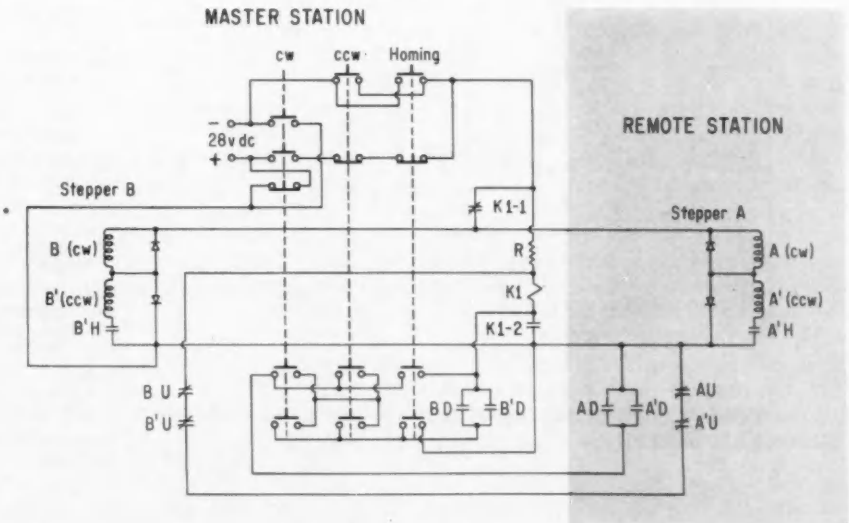


FIG. 5. AUTOMATIC STEPPING AND HOMING.

are connected in parallel, and relay contact K1-1 is normally-closed so that a 28 vdc input signal may be applied in either polarity. Across the input terminals are the K1 relay coil, a normally-open contact K1-2 which locks in the coil, and the series resistor R. Armature up contacts *BU*, *B'U*, *AU*, and *A'U* are in series as shown; armature down contacts *BD*, *B'D*, *AD*, and *A'D* are in series parallel.

The circuit operates as follows: When an input of one polarity is applied coils *A* and *B* are energized, causing armatures *A* and *B* to start down. Contacts *BU* and *AU* are interrupted, removing the short circuit across relay coil K1. When both armatures reach bottom, contacts *BD* and *AD* close, actuating relay K1, opening contact K1-1 and closing contact K1-2. The opening of contact K1-1 deenergizes coils *A* and *B*, allowing the armatures to start up. Contacts *AD* and *BD* open, but coil K1 remains energized.

When both armatures are up, contacts *AU* and *BU* close, shorting out relay K1 through resistor R. The cycle is then repeated. A pulse of the opposite polarity causes a similar sequence in the other direction.

Note that complete monitoring occurs for each armature in both its up and down position, thus providing absolute interlock. For example, assume that in the above case, coils *A* and *B* were energized, but that armature *A* failed to reach bottom (stepper did not step). In this case, contact *AD* would not have closed, and relay K1 would not have been energized. This would prevent contact K1-1 from opening. Thus armature *B* would remain down and no further stepping could take place.

Interlock deactuation during homing

It is often desirable to provide a "homing" mode during which two or more interlocked steppers can

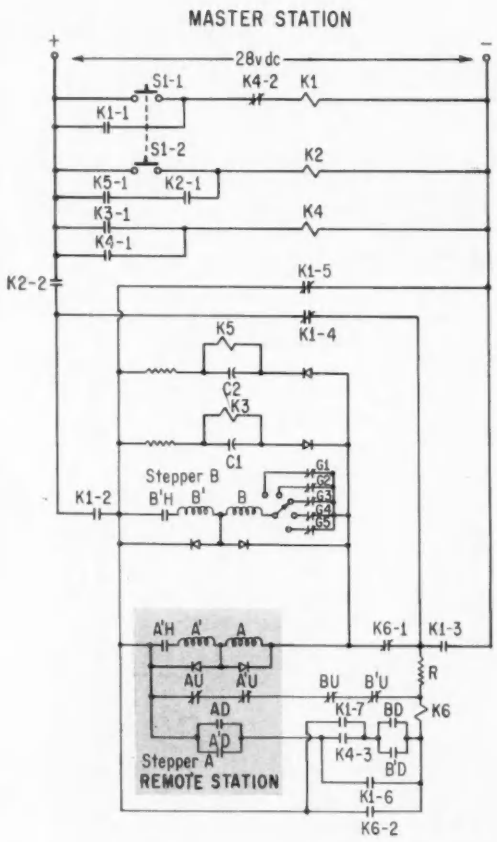


FIG. 6. AUTOMATIC HOMING BEFORE INTERLOCKED STEPPING.

SEQUENCE OF OPERATIONS (of circuit in Figure 6)

COMPONENT	CONTACT	FUNCTION
S1	1	Connects K1 (momentary).
K1	1	Locks in K1.
	2 3 4 5	Reverse polarity of 28-vdc supply to enter homing (ccw) mode. When a particular setting is called for, both steppers return automatically to home position before stepping to new position.
	6 7	Connect down contacts AD, A'D, BD, and B'D in parallel so as to deactuate the stepping interlock during the homing cycle.
S1	2	Connects K2 (momentary). Simultaneous with S1-1.
K2	1	Locks in K2.
	2	Connects 28-vdc supply to steppers.
K3	1	Energize K4 at end of homing cycle. K3 does not operate during the homing cycle because of its associated RC circuit, which prevents it from responding to the short stepping pulses. At end of homing cycle, K6-1 remains closed, permitting a dc voltage to build up across C1 and actuate K3.
K4	1	Locks in K4.
	2	Deenergizes K1. Removes parallel connection of down contacts AD, A'D, BD, and B'D by opening K1-6, 7. Restores cw polarity of 28-vdc supply by opening K1-2, 3, and closing K1-4 and K1-5.
	3	Connects down contacts AD, A'D, BD, and B'D in series-parallel to establish stepping interlock.
K5	1	Deenergizes K2 at end of interlocked stepping cycle, which causes K2-2 to open, and shuts off voltage source from steppers. Responds in manner similar to K3, above.
K6	1	Maintains power connection (cw or ccw) for each step until armatures are down, at which time K6 is energized through down contacts AD, A'D, BD, and B'D and K6-1 is opened.
	2	Locks in K6 when armatures reach bottom. K6 stays energized until armature up series contacts AU, A'U, BU, and B'U short it out through R.
G1	1 2 3 4 5	Opens stepper cw stepping circuit when predetermined shaft angle is reached.

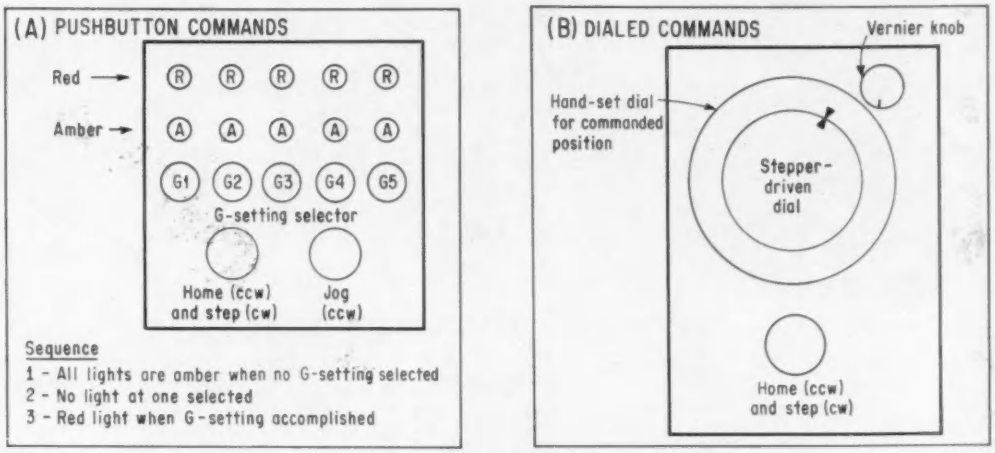


FIG. 7. INTRODUCING STEPPER COMMANDS.

return *independently* to fixed reference positions. These positions represent zero or "home" for the interlocked steppers. During the process of stepping back to "home" the interlock is removed. Figure 4 shows how this can be accomplished. It involves just two changes in the circuit of Figure 3:

(1) The *A'H* and *B'H* contacts have been added to the counterclockwise coils. These are the index contacts by which the stepper shuts itself off upon arriving home. They are open in the home position; closed in all other positions.

(2) The interlock is removed by placing contacts *AD*, *A'D*, *BD*, and *B'D* in parallel, instead of series-parallel, as in Figure 3. This removes the "mutual step completion" feature, permitting either stepper to step at will until it homes, regardless of what position the other may be in.

Circuit operation is similar to that of Figure 3 except that relay K1 is locked in independently by closure of *either BD* or *AD*, rather than by closure of both. This relinquishes the interlock between steppers A and B during selected homing periods.

Remote locations permanently connected

Where two or more steppers are in remote stations not subject to cable disconnect or other circuit disturbance, it may be assumed that synchronism is maintained. Thus a periodic or cyclic return to the "home" or basic reference position is not necessary every time a new position is commanded.

In the circuit of Figure 5, the features of Figures 3 and 4 are combined to show how the following types of stepping may be derived from one interlocking circuit, with or without return to reference home after each step sequence:

- Automatic clockwise stepping
- Automatic counterclockwise stepping
- Automatic counterclockwise homing

Controlled stepping in either direction may be obtained with slight modifications.

The upper switching section reverses pulse polarity to accomplish clockwise or counterclockwise rotation. Homing is also in the counterclockwise direction in this circuit. The lower array of switch contacts provides temporary interlock deactuation for purposes of homing as explained above.

Noted that the interlocks are achieved with *only four wires* between remotely located stations.

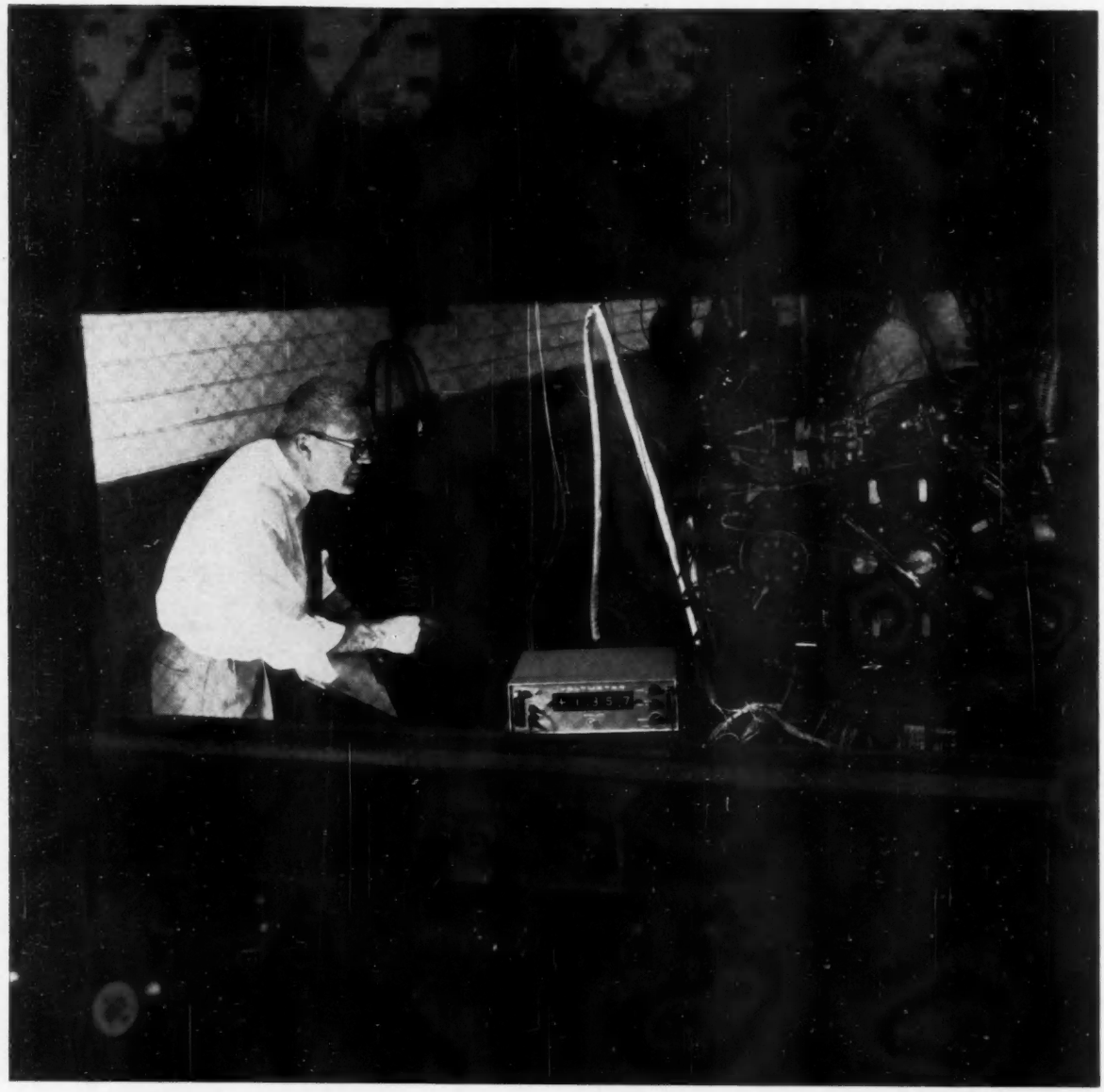
Remote locations subject to disconnect

In certain cases, such as missile launching, continued synchronism cannot be assured because of intervening periods of inactivity or test work during which instrument settings may be disturbed in a number of ways.

One way of overcoming this uncertainty of continued synchronism is to provide for automatic or manual return to a reference home whenever the control is set in operation or new remote settings are commanded. When the stepper returns to home, the new command setting is set in either manually or automatically.

In Figure 6, for example, two interlocked steppers are arranged to provide completely automatic counterclockwise return to home, followed by a clockwise interlocked advance to a new (or to the same) position. The input command can be introduced either by setting a dial or pressing an appropriate button. The complete operating sequence for this arrangement is given in the table accompanying the circuit diagram.

Figure 7 illustrates two representative control panel arrangements. In the pushbutton arrangement (Figure 7A), the selector buttons marked G1 through G5 correspond to the similarly numbered contacts in Figure 6. Figure 7B shows a dial selector as an alternate arrangement. This method requires a less complex arrangement of contacts on the stepper output shaft, and permits a much wider choice of fixed settings.



NO STEPPING SWITCHES IN THIS ULTRA-RELIABLE DVM: Cubic announces a new digital voltmeter design that eliminates stepping switches and, with them, the need for periodic maintenance. The new Cubic V-70 uses the same ultra-reliable reed relays developed for submarine cables. These reed relays are sealed in glass and have practically unlimited life. They are noiseless and completely unaffected by operating position.

Accurate: The V-70 reads any d-c voltage from 0.001 to 999.9 volts with an absolute accuracy of 0.01% plus or minus 1 digit. The Cubic V-70 Digital Voltmeter provides these and other premium features at a cost of only $1,580. For details, write to Dept. CT-104, Industrial Division, Cubic Corporation, San Diego 11, Calif. (in Europe: Cubic Europa S.p.A., Via Archimede 185, Rome).

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Autocompensation of Errors in Gyros and Accelerometers

J. M. SLATER, Autonetics Div., North American Aviation, Inc.

THE GIST: Fixed but unknown errors in a measuring device can often be eliminated by reversing the device so that the errors cancel out over a number of plus-minus cycles. Author Slater shows how this technique, known as autocompensation, can be applied to improve the long-term accuracy of inertial guidance systems.

Precision made gyros and accelerometers have good enough short-term stability, but over a long period of time they inevitably tend to drift. Unfortunately for the designer, long-term stability requirements are becoming increasingly severe. Instruments are expected to come out of a 30-day submarine cruise or to arrive, after a year's journey, in the vicinity of Mars in perfectly adjusted condition. Any method which can eliminate or substantially reduce the effect of slowly changing biases over long periods of time is of great practical importance. Autocompensation, the elimination of errors by methods that are independent of any

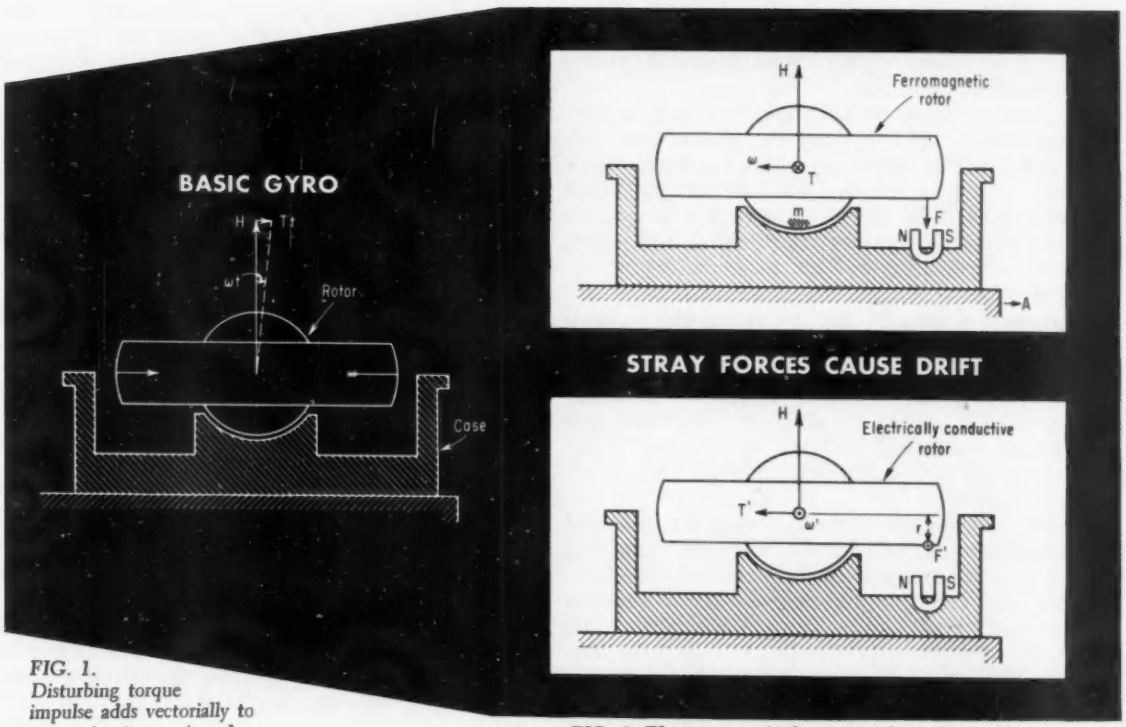


FIG. 1. Disturbing torque impulse adds vectorially to gyro rotor torque impulse.

FIG. 2. Magnetic attraction and mass unbalance produce disturbing torques.

FIG. 3. Electromagnetic drag is another source of error.

source of information external to the instruments has proved capable of doing this in field use.

Autocompensation of gyros

A gyro is most simply visualized as a spinning rotor supported by a frictionless ball-and-socket-joint so as to have freedom to spin and tilt relative to the case, Figure 1. Pickoffs and servo systems (not shown) make the case follow the rotor. The pickoffs sense relative deflection of case and rotor, and the servos drive the case into realignment. Of course, the spinning rotor exhibits a stiffness (resistance to deflection) from any preset direction in space. This property, which gives the gyro its utility as a space reference in stabilizing platforms, can be explained as follows. An applied torque impulse, *torque* times *time*, or Tt, adds vectorially to the rotor torque impulse (angular momentum) H as indicated. If H is large compared to Tt, drift angle ωt will be small.

Any practical gyro contains one or more disturbing forces which may be associated with or independent of the case. Two possible torque sources, magnetic attraction and mass unbalance, are illustrated in Figure 2. An accidental piece of magnetic material in the case (indicated schematically as a permanent magnet) pulls on a ferromagnetic rotor rim. Acting about the center of the rotor, this force produces torque T (into the page as indicated by the cross) and drift rate ω. The directions of T and ω depend on the azimuth of the case. A small mass m displaced along the rotor spin axis will also give rise to T and ω in the senses indicated when the base has a horizontal acceleration A, as shown. This torque is space-fixed and independent of anything in the case.

There are two principal approaches to gyro autocompensation: (1) to rotate the gyro case in such a manner that—assuming the disturbing torque vector moves with the case—the resulting drift rate vector will be rotated in space and hence average zero, and (2) to keep the case fixed and periodically reverse the rotor so that—assuming the disturbing torque is unaffected by such reversal—the drift rates in space in the two modes will be equal and opposite, and thus average zero.

If the case is rotated in azimuth the torque vector and drift rate vector resulting from magnetic attraction will also rotate in azimuth. Over any one complete revolution drift will average zero. But case rotation will not affect the axial mass unbalance torque and drift.

Now consider the effect of leaving the case fixed and periodically reversing the rotor spin direction. The sense of the mass unbalance torque under a steady acceleration is the same for either direction of H, so the drift rates are in opposite directions and the net drift over each cycle of rotation is zero. Magnetic attraction torque is not affected by the sense of rotor spin, so it too is compensated.

It might be inferred that case rotation takes care of case-fixed but not space-fixed torques, whereas rotor reversal takes care of both kinds. As a matter of fact, rotor reversal does generally afford more nearly complete compensation than case rotation, but the situation is not so simple as it may appear. Assume, for example, that the rotor is electrically conductive so that the magnetic material applies a drag force F' (out of the page in Figure 3 as indicated by the dot) by eddy current induction effect. Acting on moment arm r, this force produces torque T'. This torque will reverse when the rotor spin direction is reversed, so drift rate vector ω' stays the same (out of the page) and is not compensated. Such a torque, however, can be compensated by case rotation.

So far only constant disturbing torques have been considered. Torques which vary slowly compared to the case rotation or rotor reversal frequency can be considered constant, but when these frequencies and the time variations in torque are about the same magnitude matters get more complicated. For example, if the direction of lateral acceleration reverses at the same rate as the rotor is reversed, no mass unbalance torque compensation will take place. Resonance effects of this sort can result in zero improvement or even degradation in accuracy with either the case rotation or rotor reversal methods.

A quantitative argument for autocompensation may not be made because of security restrictions, but so far as the rotor reversal method (the one with which the author is personally familiar) is concerned, it can be stated emphatically that the end justifies the means. A set of gyros may come out of a long cruise with significantly altered drift rates as measured conventionally, but with extraordinarily low average drift rate as measured over a number of plus-minus cycles.

Autocompensation of accelerometers

As with gyros, stray forces or torques are a source of error in accelerometers. The simplest autocompensation method is to turn the accelerometer over periodically about an axis at right angles to the sensing axis. Any bias force will then be alternately added to and subtracted from the *mass* times *acceleration* force which the instrument is supposed to measure. Two accelerometers per axis—four or six in all for an inertial guidance system—are required, as well as a mechanism for flipping the accelerometers and switching their electrical outputs.

Autocompensation methods must not be considered a crutch. Instead, they are adaptations of old metrology techniques used wherever circumstances permit to enhance the accuracy of physical measurements. Application of autocompensation to a particular inertial guidance problem requires a thorough knowledge of the sources of disturbing torque or force and of the environment (especially time-varying acceleration) of the equipment.

$$F = 5.7 \times 10^{-7} \frac{B_m A_m m h L_g c W}{f A_g i R}$$

$$F = \sqrt{0.4 A_m L_m W}$$

Simplified Equations Speed Moving Coil Design

THE GIST: By converting an electric signal to a linear displacement, the moving coil can position a control system regulating element. The design of these coils normally involves many equations, but Author Holzbock shows how to simplify the process by making several assumptions based on the properties of typical materials.

WERNER G. HOLZBOCK, Birmingham, Mich.

Because of its low cost, low power input requirements, and relatively long stroke, the moving coil is being used as a positioning element in many control systems. The coil takes a weak electric signal and converts it into a stroke to position an element such as a flapper-nozzle. Coil motion results from the interaction of electric current flowing through the coil and the magnetic field in which the coil is located (Figure 1).

The equations governing the design of the moving coil are complex, requiring the designer to go through a long series of calculations. In many cases it is possible to use greatly simplified design equations. The following shows their development and the assumptions made, along with a sample calculation. Before applying this shortened form to a specific case, a designer should investigate the assumptions carefully to be sure they are valid.

Typical displacements and power requirements

Stroke length depends on the element that has to be positioned. Typical stroke lengths are plus or minus 0.015 in. for a flapper and plus or minus 0.080 in. for a jet pipe. Actually, motions of this sort hardly affect the force output. The difference in displacement does matter, however, with respect to dynamic response. If the maximum change in force is, for example, 0.5 lb, the necessary spring rates are then $0.5/0.015 = 334$ lb/in. for a 0.015-in. displacement and $0.5/0.080 = 62.5$ lb/in. for a 0.080-in. displacement.

The power needed to activate the coil can be quite small. Typical ranges are 10 to 250 milliwatts, 24 to 600 milliwatts, and 60 to 1,500 milliwatts.

Developing the simplified design equations

The first problem is determining the flux density in the air gap around the coil. Since flux magnitude in the air gap is directly proportional to the energy product (energy product is the demagnetization force in oersteds times the induction in gauss), and Alnico V has the highest energy product of any known alloy, it is the preferred material for moving coil magnets. To take full advantage of this material's properties, it should be used at the peak of its energy curve (Figure 2). At this point the demagnetization force is 545 oersteds and the induction or flux density in the magnet is 10,000 gauss. (Flux density in the magnet is not the same as flux density in the air gap, as will be shown later.)

Air gap flux density can be determined either on the basis of gap area and magnet area, or gap length

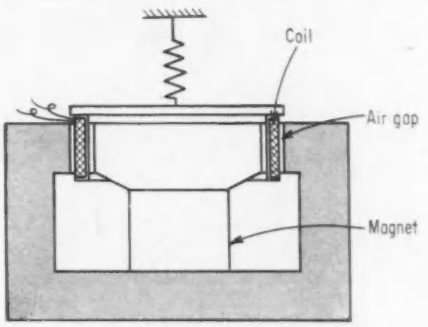


FIG. 1. Cross-section of an assembled moving coil showing its two main parts, the magnet and the sliding coil.

and magnet length. The two equations are

$$B = \frac{B_m A_m}{f A_g} \tag{1}$$

and

$$B = \frac{H_m L_m}{f' L_g} \tag{2}$$

where B is the flux density in the air gap in gauss, B_m is the flux density in the magnet in gauss, A_m is the cross-sectional area of the magnet in square inches, f is the leakage factor, A_g is the cross-sectional area of the air gap in square inches measured at right angles to the flux direction, H_m is the demagnetizing force in oersteds, L_m is the length of the magnet in inches, f' is the reluctance factor, and L_g is the length of the air gap in inches, measured parallel to the flux direction.

The leakage factor f is necessary because only a portion of the magnetic flux can be directed across the air gap. The remainder is lost by fringing when flux lines stray from the main path. Leakage factors vary from about 1.5 to very large values depending upon the magnetic circuit. A general figure that has proven reasonably reliable for moving coil structures is $f = 2.5$. Designs should always be checked with magnet manufacturers to get the greatest efficiency.

Reluctance factor f' accounts for the additional force necessary to push the flux through the soft iron material and joints which make up the magnetic circuit. It normally varies from 1.1 to 1.4, so 1.35 is a good design approximation.

When these values of f and f' along with the values for B_m and H_m obtained from Figure 2 are substituted back in Equations 1 and 2, the result is

$$B = 4 \times 10^2 \frac{A_m}{A_g} \tag{3}$$

and

$$B = 4 \times 10^2 \frac{L_m}{L_g} \tag{4}$$

Equations 3 and 4 can be combined into the relationship

$$10 \frac{A_m}{L_m} = \frac{A_g}{L_g} \tag{5}$$

This means the area to length ratio of the magnet should be one tenth the area to length ratio of the air gap. This relationship is sometimes helpful in determining initial design parameters.

The air gap area A_g is the product of the medium circumference c and the height h of the air gap (Figure 3), so Equation 3 may also be written

$$B = 4 \times 10^2 \frac{A_m}{ch} \tag{6}$$

The basic equation in the cgs system to determine the force developed by a moving coil is

$$F = Bli \tag{7}$$

where F is the force in dynes; B is the flux density in the air gap in gauss; l is the total length of wire that makes up the coil, in centimeters; and i is the current in abamperes. When converted into more practical engineering units, Equation 7 becomes

$$F = 5.7 \times 10^{-7} Bli \tag{8}$$

where F is in lb, l is in in., and i is in amperes.

To determine the amount of wire that fits into the air gap, it is necessary to know m, the turns of wire per unit cross-sectional area. When finding the cross-sectional area it is sufficient to use the product hL_g. Actually, the length of the air gap cannot be filled completely with wire. Allowance has to be made for clearances, tolerances, and the thickness of the bobbin wall. On the other hand, it is practical to make the height of the coil slightly greater than the height of the air gap to utilize some of the fringe flux. These two changes compensate each other to an extent and justify using hL_g for the cross-sectional area of the winding. Since the total number of turns of wire

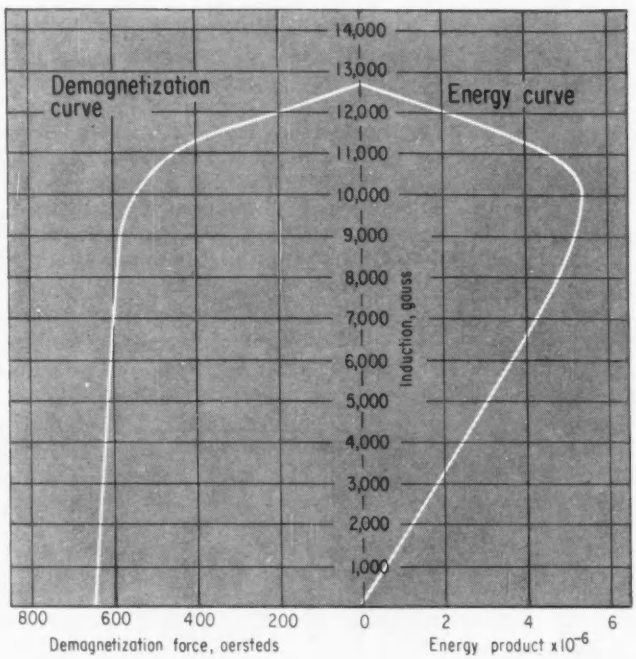


FIG. 2. Typical demagnetization and energy curves for Alnico V.

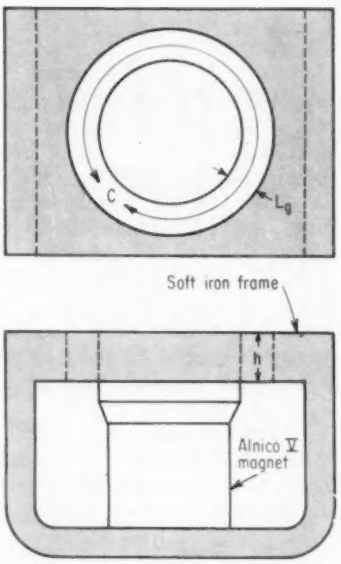


FIG. 3. Detailed drawing of the magnetic structure. L_g indicates the width of the air gap, c the medium circumference, and h the airgap height.

is given by

$$\text{turns} = mhL_g \tag{9}$$

the total length, in inches, of the wire in the air gap is

$$l = mhL_g c \tag{10}$$

Substituting Equations 6 and 10 in Equation 8 gives

$$F = 2.3 \times 10^{-8} A_m m L_g i \tag{11}$$

or, expressed as a function of signal power,

$$F = 2.3 \times 10^{-8} A_m m L_g \frac{W}{iR} \tag{12}$$

where W is the signal power in watts and R is the resistance of the wire in ohms which can be written as

$$R = \frac{nl}{1.2 \times 10^4} \tag{13}$$

where n is the resistance per 1,000 ft.

Equations 10 and 13 are now combined and the result rearranged to give

$$\frac{m}{R} = \frac{1.2 \times 10^4}{nhL_g c} \tag{14}$$

This is inserted in Equation 12, which becomes

$$F = \frac{27 A_m W}{nhci} \tag{15}$$

Solving Equation 11 for i and substituting this in Equation 15 gives

$$F = 0.25 A_m \sqrt{\frac{mL_g W}{nhc}} \tag{16}$$

The ratio m/n is very nearly constant for a given insulation thickness. For example, for Roebling magnet wire with heavy insulation the following values are given:

Wire size	m	n	m/n
36	27,700	415	67
38	41,500	648	64
40	69,000	1,080	64
42	111,000	1,660	67
44	160,000	2,590	62

Therefore, an average value of $m/n = 64$ seems justified, and Equation 16 becomes

$$F = 2A_m \sqrt{\frac{L_g W}{hc}} \tag{17}$$

The equation now contains only the dimensions of the magnetic assembly and the power of the input signal.

In those cases where the force should be expressed in terms of flux rather than magnet area, it is only necessary to substitute Equation 6 in Equation 17 which becomes

$$F = 0.5 \times 10^{-8} B \sqrt{chL_g W} \tag{18}$$

Finally, in order to express the force as a function of the magnet dimensions only, substitute $A_g = ch$ in Equation 5, solve the result for L_g and put this value into Equation 17 to get

$$F = \sqrt{0.4 A_m L_m W} \tag{19}$$

APPLYING THE EQUATIONS TO A SAMPLE PROBLEM

As an example, suppose a moving coil must be designed to work with a signal output of 60 to 1,500 milliwatts. From Equation 19, the force from a coil for 60 milliwatts is

$$F = \sqrt{0.4 A_m L_m \times 0.06} = 0.155 \sqrt{A_m L_m} \tag{20}$$

and for 1,500 milliwatts:

$$F = \sqrt{0.4 A_m L_m \times 1.5} = 0.775 \sqrt{A_m L_m} \tag{21}$$

Now a permanent magnet must be chosen. Magnet producers generally have some standard sizes, and it is wise to stick with these. The following dimensions are standard with one typical manufacturer, along with calculated values of $\sqrt{A_m L_m}$:

Diameter in inches	*Length in inches*	$\sqrt{A_m L_m}$
0.689	0.430	0.40
0.998	0.648	0.71
1.365	0.748	1.04
1.672	1.080	1.54

The largest magnet gives nearly four times the force of the smallest. This, however, is at the expense of 14 times the volume. If the volume of the largest magnet is acceptable, inserting the corresponding value of $\sqrt{A_m L_m}$ in Equations 20 and 21 shows the minimum signal force to be 0.238 lb and the maximum signal force to be 1.19 lb.

Now it is necessary to see if static friction is sufficiently low for this force level so the dead band remains within acceptable limits. The dynamic response should also be checked by determining what

stroke and hence what spring is required. The mass to be moved can be estimated and the approximate natural frequency determined.

The signal range expressed in units of force is $1.19 - 0.238 = 0.952$ lb, or just about 1 lb. If a dead band of 0.1 percent of signal range is desirable and backlash is negligible, the static friction must then be not more than 0.001 lb. As for dynamic conditions, let the stroke be plus or minus 0.08 in. This calls for a spring rate, k, of $1/0.08 = 12.5$ lb/in. The weight of the movable parts, W, including coil, is estimated at 0.2 lb. The resulting natural frequency is

$$f = \frac{1}{2\pi}\sqrt{\frac{kg}{w}} = \frac{1}{2\pi}\sqrt{\frac{12.5 \times 386}{0.2}} = 24 \text{ cps}$$

The frequency response of the coil must be somewhere below this value.

The next step is to determine the dimensions of the air gap. To obtain a simple design, the air gap inside diameter is made approximately the same as the diameter of the permanent magnet, so a value of $D_i = 1.7$ in. is chosen.

Air gap length is somewhat arbitrary since there are two opposing considerations:

1) The air gap should be as narrow as possible to reduce magnetic leakage due to fringing.

2) The air gap should be as wide as possible to reduce the percentage lost for the thickness of the bobbin wall, clearances, and tolerances.

Since the space required for bobbin wall, clearances, and tolerances is about 0.02 in., an air gap of $L_g = 0.2$ in. seems reasonable. Equation 5 is now used. Inserting values gives

$$10\,\frac{2.2}{1.08} = \frac{A_g}{0.2} \text{ or } A_g = 4.07 \text{ sq in.}$$

The inside diameter of the air gap was chosen to be 1.7 in. with an air gap length of 0.2 in. The medium diameter of the air gap is 1.9 in., and the medium circumference is 5.96 in. Since the area A_g of the air gap is to be 4.07 in., the height must be $4.07/5.96 = 0.68$ in. Flux density in the air gap can be determined from Equation 3.

$$B = 4 \times 10^3\,\frac{2.2}{4.07} = 2{,}160 \text{ gauss}$$

Before completing the design of the magnet structure, a few additional dimensions must be considered: the air space between the wall of the permanent magnet and the side wall is usually chosen to be about ½ the diameter of the permanent magnet to limit sidewise leakage. Material for the magnetic structure should be a soft iron, with a thickness of about 15 percent of that of the permanent magnet. A detailed calculation of the reluctance can be made with the help of a suitable handbook. However, with air gaps as considered, the contribution of the iron is extremely small.

Now the coil can be calculated. It was mentioned before that the coil may be slightly higher than the air gap to utilize some of the leakage flux. A height of 0.75 in. is chosen. The bobbin wall thickness is assumed to be 0.008 in., and 0.006 in. is allowed on either side for clearances and tolerance. This gives a coil I.D. of $1.7 + 0.012 + 0.016 = 1.728$ in. and an O.D. of $2.1 - 0.012 = 2.088$ in. The medium diameter is 1.908, giving a medium circumference of 6 in., which is nearly the same as the air gap circumference of 5.96 in. The cross-sectional area of the coil is $0.75 \times 0.18 = 0.135$ sq in. This is practically equal to that of the air gap, $0.68 \times 0.20 = 0.136$ sq in.

The initial signal input was 60 to 1,500 milliwatts, corresponding to 10 to 50 milliamp into a 600 ohm load. It is assumed that connecting wire resistance is negligible, otherwise the resistance would have to be subtracted from the 600 ohms.

The value $m/n = 64$ is generally valid for magnet wire with heavy insulation; therefore,

$$mn = \frac{m}{n} \times n^2 = 64\,n^2 \qquad (22)$$

Substituting this in Equation 14 and inserting values, gives

$$n = 13.7\sqrt{\frac{600}{6 \times 0.135}} = 370 \text{ ohms per 1,000 ft.} \qquad (23)$$

In applying this equation, it is irrelevant whether the dimensions of the air gap or the coil are used, since the values for c and hL_g are practically the same for both.

Wire tables give a resistance of 331 ohms per 1,000 ft for No. 35 wire, and No. 36 wire has a resistance of 415 ohms per 1,000 ft. The required value lies in the middle. No. 35 wire must be ruled out, since 600 ohms of this wire would not fit into the available space. The designer has several choices. He may 1) obtain No. 35½ wire which, while not standard, is available; 2) use No. 36 wire and be satisfied with the lower force level, but require less space for the coil and hence have the benefit of larger tolerances; or 3) work backward by using the No. 36 wire, determining chL_g from Equation 23, and designing an adequate air gap on this basis. In this case, alternative 2 is chosen. A check can be made by using Equation 8. The length of No. 36 wire would be

$$12 \times 10^3 \times \frac{600}{415} = 17{,}350 \text{ in.}$$

The flux density as determined previously is 2,160 gauss, and the maximum signal current is 0.05 ampere. Hence,

$$F = 5.7 \times 10^{-7} \times 2{,}160 \times 17{,}350 \times 0.05 = 1.07 \text{ lb}$$

Previously, a maximum available force of 1.19 lb was calculated using Equation 21. The difference is the loss due to incomplete utilization of space. This loss is small, however, and the gain in tolerances may be well worth it.

Priority Interrupt in Control Computers

THE GIST: Most digital computers now are able to interrupt a program being run so that another program of more immediate importance can be completed as quickly as possible. The idea of interruption implies that any partial results are saved so the first program does not have to be restarted but can be picked up again where it was interrupted by the higher priority program. Priority interrupt capability is particularly important in control computers. It can be written into any general-purpose computer program or wired into the computer when it is built; the latter has real advantages in terms of safety and profitability in control applications because priority testing and program switchover times are much shorter. Automatic initiation and running of emergency, alarm, diagnosis, and even routine maintenance programs is made easy by cascading priority interrupts.

S. B. DINMAN
R. W. SONNENFELDT
Radio Corp. of America

Industrial control computers must digest input data as it arrives without going through intermediate buffer storage such as punched cards, drums, or magnetic tapes. In this they differ fundamentally from business data processors or scientific data processors in usual office use. For safety and profitability, the industrial control computer must be available at all times to attend the needs of the process, no matter what else it may be used for when process demands are slow. In short, where many business data processing systems can be computer-oriented, an industrial control computer must be process-oriented.

Inevitably, therefore, process control computers are developing distinct features of their own, and the most important of these is called "priority interrupt". This feature more than any other enables a computer to adapt itself to the pace of process requirements. Priority interrupt makes comprehensive pre-planning of the computer's work load possible, because it provides immediate computer response to malfunctions in the process or even within the computer itself.

Priority interrupt can be simulated or implemented

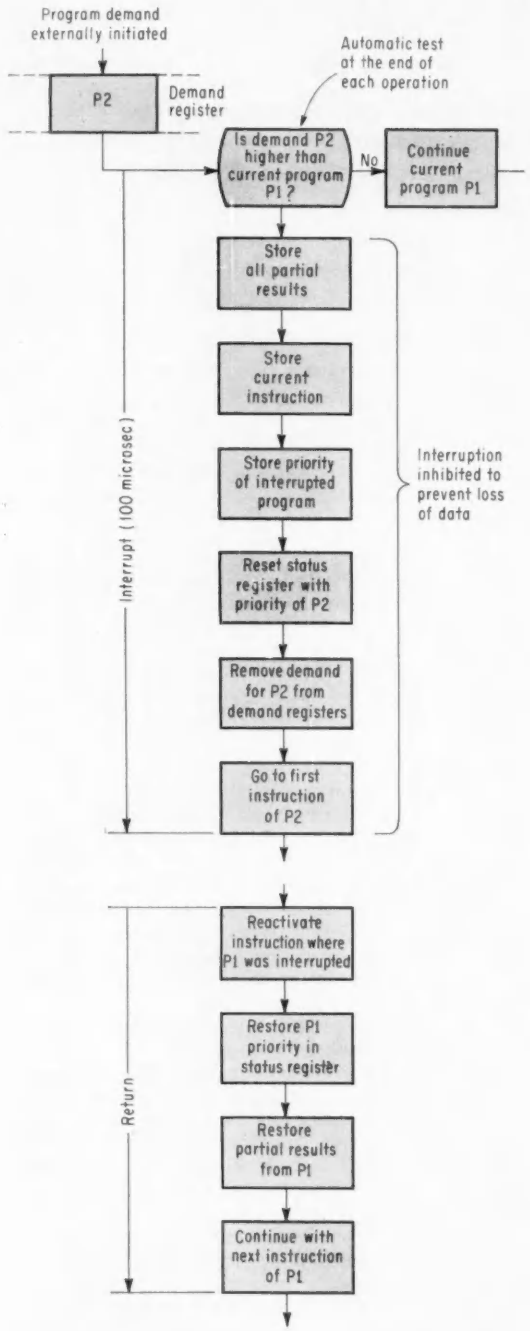
As with all other computer logic operations, two approaches are possible when adding priority interrupt capability to a general-purpose computer design: the necessary logic can be added as a special program subroutine in the computer memory, or it can be permanently wired into the computer. The first approach can be called a simulated priority interrupt; the second is an implemented interrupt. Figures 1 and 2 make a side-by-side comparison of these two approaches.

The implemented priority interrupt in the RCA 110 control computer employs a unique "priority status" register in a system designed by G. C. Hendrie, L. W. Honens, and S. B. Dinman. The priority status register holds a priority symbol for the program currently running. Demands for action from the process cause appropriate priority symbols to be set into a second register called the "priority demand" register.

The computer compares the priority symbols in the status and demand registers after each operation in the program being run (every few microseconds in the 110). If the priority symbol of the action demanded is higher than that of the current program in the status register, the computer immediately interrupts the current program and switches automatically to the demanded program, as in the flow chart in Figure 1. If the priority demanded is not higher, the computer simply goes on to the next instruction in the current program.

The functions performed automatically in the implemented system can be simulated by inserting special instructions in a computer program. In this case, a priority comparison requires several program instructions to determine whether the running program should be interrupted, see Figure 2. Each program step takes time, and

Implemented Interrupt vs Simulated Interrupt


Program demand externally initiated
P2
Demand register
Automatic test at the end of each operation
Is demand P2 higher than current program P1?
No
Continue current program P1
Store all partial results
Store current instruction
Store priority of interrupted program
Reset status register with priority of P2
Remove demand for P2 from demand registers
Go to first instruction of P2
Interrupt (100 microsec)
Interruption inhibited to prevent loss of data
Reactivate instruction where P1 was interrupted
Restore P1 priority in status register
Restore partial results from P1
Continue with next instruction of P1
Return

← IMPLEMENTED

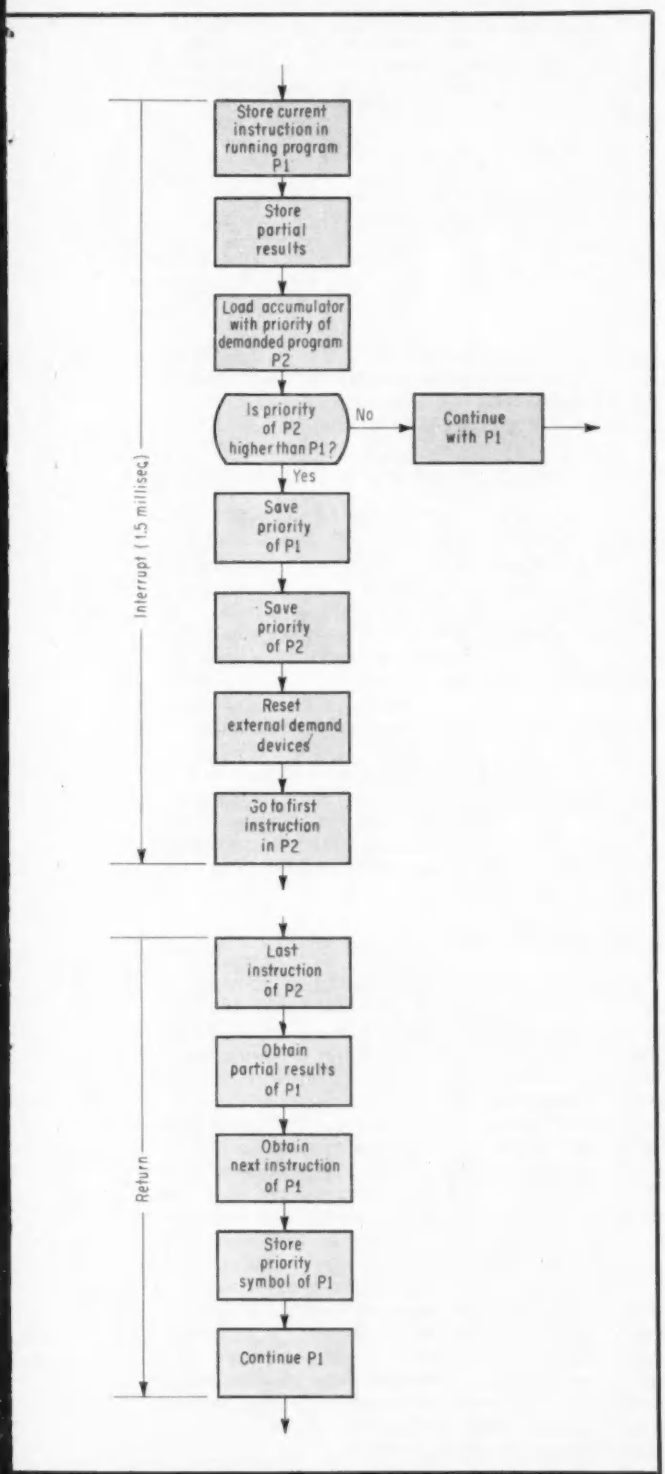
FIG. 1.
Steps in an implemented (wired) priority interrupt system. Numbers representing priorities of program currently running P1 and program demanded by process P2 are stored continuously in "priority status" and "priority demand" registers, compared every few microsec after each computer operation. If current program priority is higher, program is continued at next step. If demanded program priority is higher, results of current program to this point are stored for later return to same point in program. The address of the next instruction of the current program in the core memory is then stored in a standard memory location. Then the priority of the interrupted program is stored for later reference. Next, the computer sets the priority symbol of the new program in the priority status register and removes it from the priority demand register. It then goes to the first instruction of the demanded program, which is picked up from a preassigned memory location. At the end of this instruction the computer scans the priority status register and can interrupt again as needed.

After execution of the demanded program the computer returns to the interrupted program. First, it goes to the standard memory location where it stored the next instruction to locate the correct place in the program. Next it restores the priority symbol in the status register, then recalls the partial results and continues with the interrupted program.

SIMULATED →

FIG. 2.
Steps in a simulated (programmed) priority interrupt system. Before a comparison of current and demanded program priorities can be made, a simulated interrupt program must provide for removal of the current partial results from the computer accumulator or adder so that the symbols corresponding to the priorities demanded can be entered. If the current program priority is higher than the priority of the program demanded, the computer returns to the next instruction in the current program. But the time required is significantly longer for the priority comparison than in the implemented priority interrupt system. This comparison time lost makes the simulated interrupt much less efficient and hence less useful. If the comparison indicates priority for the demanded program, the programmer must provide additional instructions for storing addresses of partial results and the priority symbol of the interrupted program, then start the new program.

The steps in the computer's return to the interrupted program are similar to those in the implemented system, except that these steps must be provided as specific instructions in a stored program.


Store current instruction in running program P1
Store partial results
Load accumulator with priority of demanded program P2
Is priority of P2 higher than P1?
No
Continue with P1
Yes
Save priority of P1
Save priority of P2
Reset external demand devices
Go to first instruction in P2
Interrupt (1.5 millisec)
Last instruction of P2
Obtain partial results of P1
Obtain next instruction of P1
Store priority symbol of P1
Continue P1
Return

total comparison time alone is several times that in the implemented case. Thus, priority testing after each operation may not be practical at all unless the basic computer speed is increased appreciably (and the speed of many control computers is already pressing the practical state of the art). Even less frequent testing may use so much time that computer efficiency in working out the control problem is crippled.

When the result of the priority test does interrupt the running program, the total time from test to the first step of the demanded program is also shorter for the implemented than for the simulated priority system. The total time for automatic interrupt on the 110 is about 100 microsec. A simulated interrupt on a machine of the same basic speed requires 1 to 1½ millisec.

Interrupts can be cascaded for safety and efficiency

An implemented priority interrupt has another decisive advantage in its ability to handle repeated interrupts efficiently. Repeated interrupts lead to very serious difficulties in a program simulated priority interrupt system because the sequence of interrupt demands cannot be predicted: the demands arise from process events not under program control. The computer with an implemented priority interrupt system always returns (if only momentarily) to the last previous program, so it will finish in turn every unfinished program as permitted by the current priority situation. Because it can return to any point of an interrupted program, an implemented priority interrupt equipped computer can handle peak emergency loads as readily as ordinary "housekeeping" tasks during otherwise free time when there are no critical process demands.

The priority status diagram of Figure 3 shows a sequence of events that could occur. The process demands a program P3 with priority 3 while the computer is running a program P1 with priority 1 (the lowest priority). The computer switches to P3 without finishing P1, but stores the partial results for later return. While P3 is running, a demand for P5 occurs and because P5 has a higher priority than P3, the computer switches to P5 without finishing P3. But it again stores the partial results for later return. Then, while P5 is running, the process demands P6. If P5 and P6 have the same order of priority, the computer finishes P5 before starting P6. While running P6, a demand for P4 occurs which does not constitute an interruption. When P6 is finished, to computer attempts to return to P3, but just before the first instruction of P3, recognizes the demand for P4 and switches to P4. At the end of P4, it returns to P3 and, after execution of P3, it eventually returns to P1, the lowest priority program.

It is very difficult to write a computer program that automatically steps up and down through these priority requests, always executing a currently demanded program with the highest priority and returning to each unfinished program in turn according to the existing priority request

Cascaded Interrupt . . .

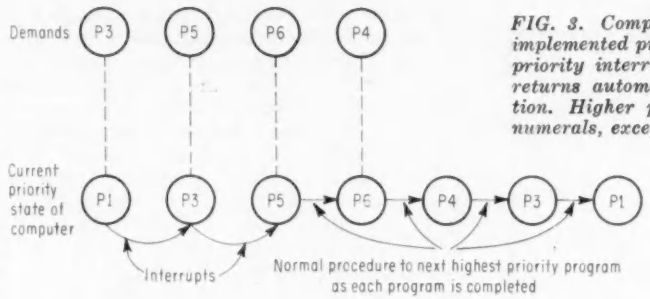


FIG. 3. Computer priority status diagram for implemented priority interrupt system shows how priority interrupts are cascaded by system that returns automatically to the point of interruption. Higher priorities are indicated by higher numerals, except P5 equals P6.

situation. The housekeeping instructions required to ensure optimum action become so numerous and have to be executed so frequently that, in the presence of cascaded demands for priority interrupt, a simulated priority system soon becomes hopelessly inefficient.

Examples of Automatic Priority Interrupt

1. Automatic maintenance

If priority 1 is assigned to an automatic maintenance program, the computer will automatically run such a program whenever no other program is demanded. Figure 4 shows a flow chart for a typical program that would run sample calculations with known data and check the validity of the answers. Such a program would also exercise computer instructions under worst conditions of data and then test for errors. The computer would then print out proof of the successful test. When finished, the computer could rerun the sequence until the process demanded a priority interrupt, or it might go to standby for a time.

If the automatic maintenance routine discovers errors, a typical program might turn process control over to a safe manual position and then automatically run a diagnostic procedure on the computer to find the source of the error and print out the diagnosis for immediate correction by a maintenance technician.

Notice that the automatic preventive maintenance routine normally can be interrupted at any time by process priority demands so that the computer-controlled system stays "up", and performance verification needs no human intervention.

Comprehensive tests can be planned in such programs since interrupted tests will be continued from the point of interruption when free time is again available. In other words, with an automatic priority interrupt system, a maintenance routine that runs for 10 min can be done in many small segments, perhaps spreading the total running time over several hours. Without a priority interrupt system and its provision for storage of partial results, the computer must work to complete rather than partial results each time the maintenance routine is run. For all practical purposes, such a system is "down" when maintenance procedures are being run, so simpler, shorter maintenance routines must be used.

2. Automatic diagnosis of alarm

Another example of the use of priority interrupt is automatic handling of alarm routines, Figure 5. When a process alarm is detected an automatic priority interrupt system can jump automatically to an alarm handling routine. In a typical sequence the system re-reads the alarm device a number of times to make sure that the condition is not merely transient. If the alarm persists, the computer samples a standard input and then tests whether the standard reading is within prescribed tolerances. If it is out of tolerance, the computer has diagnosed a computer system malfunction and jumps to a diagnostic routine. If the reading of the standard is within tolerances, the computer then sounds a confirmed process alarm, prints out related information, and jumps to the proper process alarm routine.

3. Power failure priority interrupt

Automatic priority interrupt also provides a way to prevent computer information being lost during a transient power failure. A power failure alarm causes the computer to jump automatically to the alarm routine, Figure 6. If the alarm is confirmed as a power failure, the computer then stores all current partial results in static nonvolatile registers and then halts. When power returns, partial results are read back into "dynamic" drum and flip-flop registers and the computer takes up where it left off. It is not even necessary to restart a program. Without this protection against transient power failures, it is normally necessary to reload programs into the computer from paper tape or cards, which may require many minutes or even hours. A computer inherently protected against transient power failures is much easier to switch onto an emergency power supply in case of a general power failure and will come back on line immediately with no loss of program or partial results.

. . . and Some Automatic Features it Makes Possible

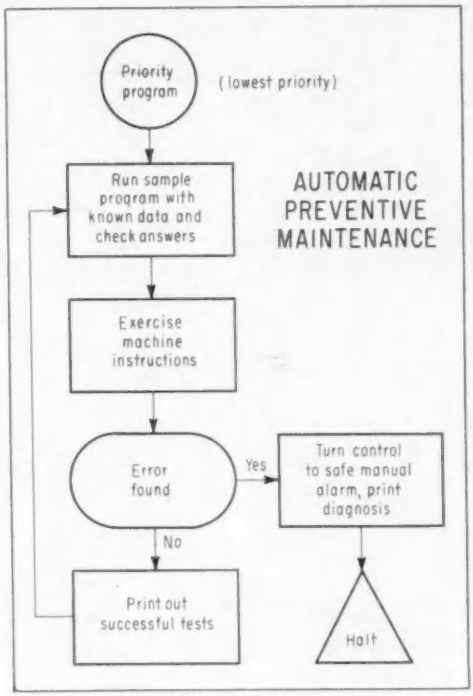


FIG. 4. Program for preventive maintenance can be given lowest priority and will be run (from last point of interruption to next interruption) whenever no other program is demanded by process or operator.

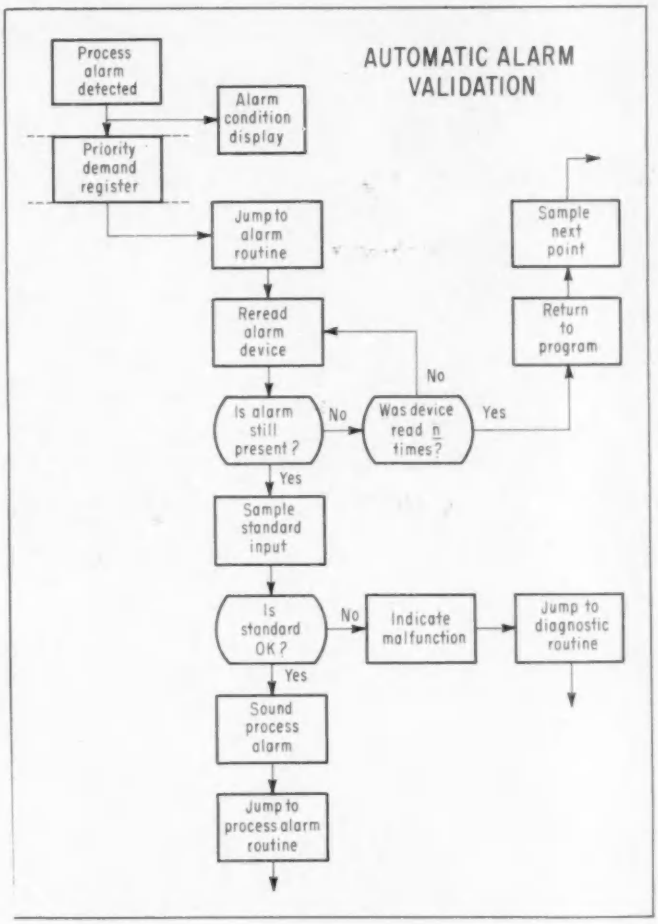


FIG. 5. Emergency alarm on process can automatically interrupt any running program and check proper operation of alarm to indicate system malfunction before jumping to alarm routine.

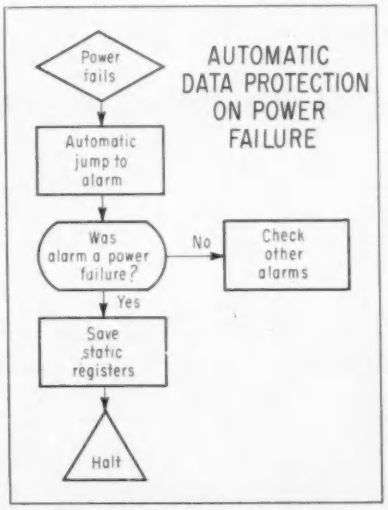
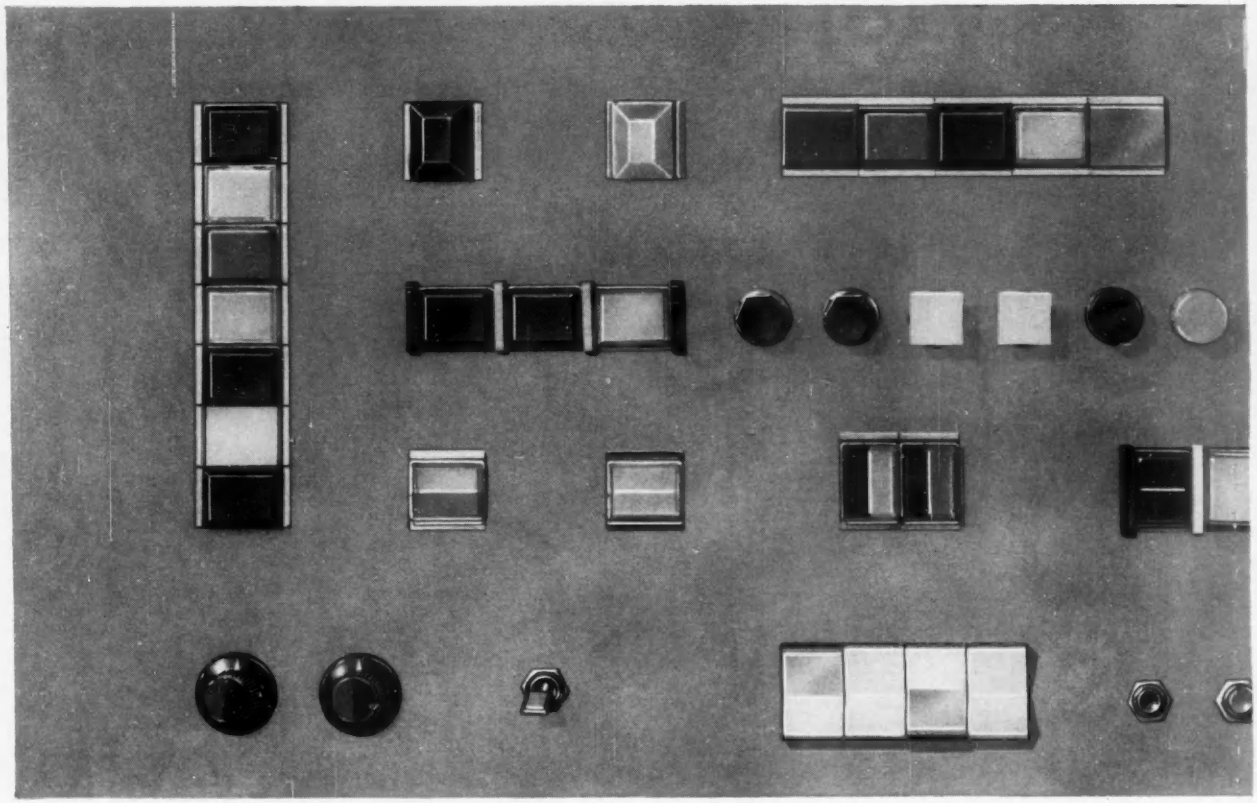
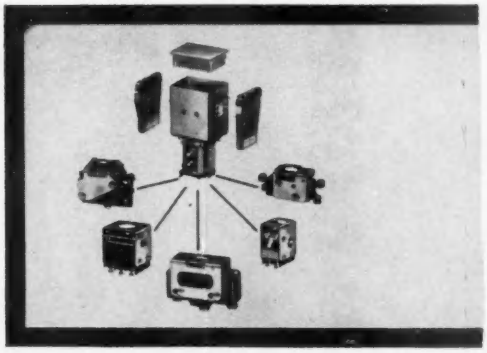
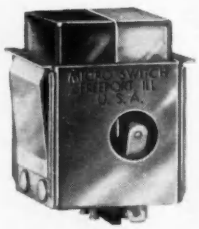


FIG. 6. A confirmed power failure alarm can cause computer to remove all data from volatile drum and flip-flop registers and store them in nonvolatile core memory before shutting down, thus permitting restart at same point in program when power is returned by normal or emergency supply.







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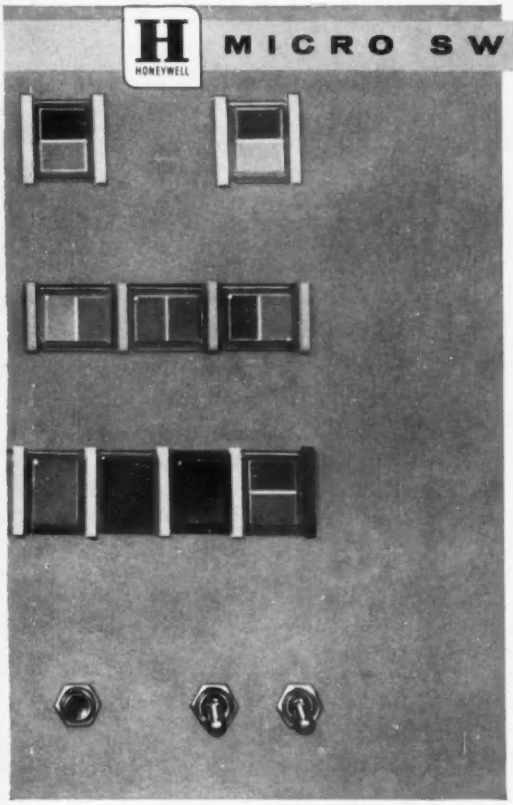

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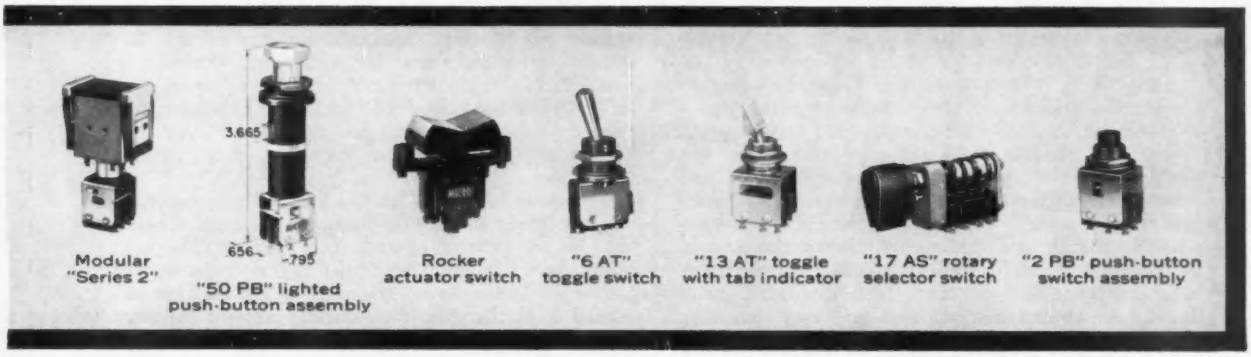

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Information System Controls Rocket Engine Reliability

Complete reliability data on every component in every rocket engine manufactured by Rocketdyne is now available to their engineers and management from a new system for fast recording and processing of test failure data. The new system is called RAPID, is built around an IBM 7090, and collects its data from every test made on any controlled component from research and development phases through operational launching of a missile. RAPID controls over 1,300 components.

GORDON E. OLSON
Rocketdyne

Rocketdyne has developed and put into operation a unified information system to control the reliability of liquid propellant rocket engines. The system uses an IBM 7090 large-scale computer to store and process a large amount of data from tests made on components and systems at every stage from research and development to final operational testing at field installations. The new information system is called RAPID, for Rocketdyne Automatic Processing of Integrated Data, and extends a common pooling of data which had already existed between three major departments—engineering, quality control and field engineering.

The new system puts onto magnetic tape one universal bank of information on engine tests, and removes the differences that existed in the previous reporting systems. Its flexibility enables the computer to search and sort records in as many ways as there are items of information to control in the basic record. In this case there are 1,300 such items. As an example, all data on every test ever made on a special serial-numbered component can be retrieved immediately to determine its history previous to a failure.

RAPID receives a great variety of information relating to engine development, manufacture, and test. With this information, the system can put before an executive at any time full reports on any aspect of Rocketdyne's business of manufacturing rocket engines for the Atlas, Thor, Jupiter, and Redstone ballistic missiles, and the H-1 engine for the NASA Saturn project. More than 50,000 data records are already banked on magnetic tape, some dating back to 1958.

One of RAPID's most important contributions is the compilation of reliability factors on components. A reliability factor is the ratio of the number of successful tests on a particular kind of component to the total number of tests on that component, and is an expression of the probability that the component will perform satisfactorily. On the earlier computer system, reliability factors could be compiled only on complete engines, though failure data was retrievable for components.

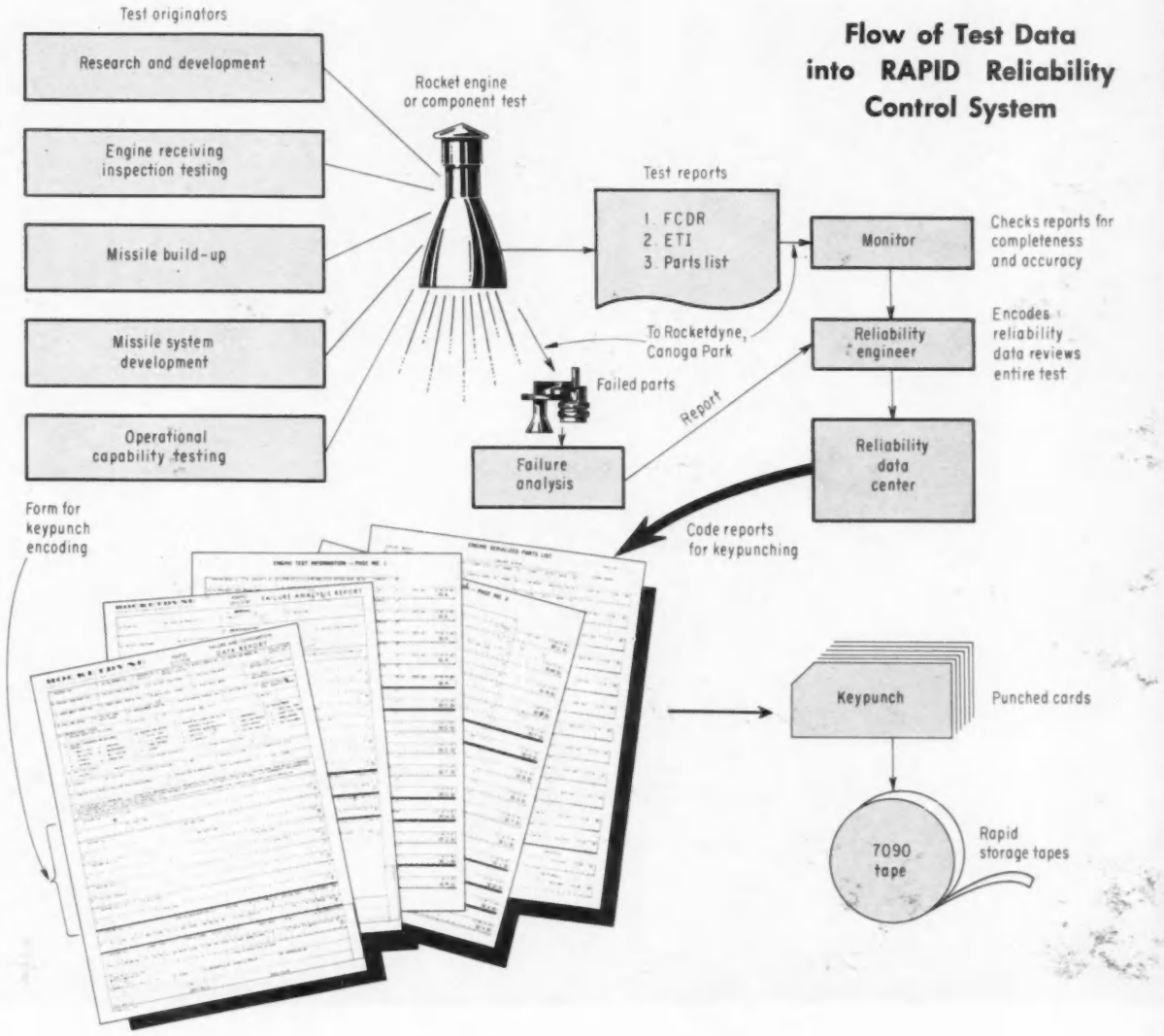
How the RAPID system works

RAPID receives detailed information on all the failures occurring on all Rocketdyne products, from a torquing problem with a bolt on an acceptance test firing to a turbopump malfunction that happens in a countdown on the launch pad. This test failure information originates in one of the five general areas shown at the upper left in the flow diagram of the RAPID system. It is transmitted to RAPID at Canoga Park, Calif., on a failure data report (FCDR), which tells what part failed, the nature of the failure, and the cause of the failure if possible.

The received FCDR is checked for completeness and accuracy and coded on a special form (lower left in the flow diagram) for keypunching into input cards for RAPID. If the cause of the failure cannot be determined, the part itself may be returned to Rocketdyne for analysis, after which the failure analysis report also would be coded for entry into RAPID. The failure analysis program results in changes varying from design modifications or a change in component specification to establishing a better handling procedure.

An engine test information (ETI) report carries the data on every engine hot-firing, including basic test parameters and an over-all test evaluation. The information on field tests such as static firings and launchings is teletyped to Rocketdyne for entry into RAPID.

For the compilation of component reliability factors, RAPID also receives a parts list breakdown by component serial number for every rocket engine. In compiling these factors, RAPID scans the component serial number list for each engine as FCDRs, ETIs, and FARs arrive, and stores them against each serial number. The serial number for



each new component added to an engine brings the parts breakdown for that engine up to date.

Uses for the magnetic tape records

The RAPID system divides its basic record on magnetic tapes into two sections: engine test information and failure information. An unusual feature is the inclusion in the magnetic records of a narrative description of both a test and all of its failures.

The IBM 7090 used in the RAPID system has ten channels through which stored information on the magnetic tapes can be transferred by the computer into the core memory for processing at speeds up to 10,400 words per sec.

A user can ask the system to do three basic operations: search for all information of a specified kind; sort this information in a specified order; or write this information on a magnetic tape in a specified format. The mathematical expression for designating qualifying conditions to the computer is an infinite expansion, so there is no limit to the number of ways that information can be searched for or sorted. In RAPID, the number of ways of searching and sorting becomes astronomical when just a few of the 1,300 control items are used in the expression.

Because of its flexibility, RAPID has become much more than just a system for computing reliability factors. Engineers use it for preparing reports for the Air Force and for making special studies. Quality control uses it as a tool for investigating trouble areas. And field engineers use it for preparing statistical failure studies.

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A customer's functional acceptance test of this new Weston Cryogenic Valve showed *zero leakage* of helium at −320°F, after 1200 test cycles! Direct operated and electrically controlled, this three-way airborne valve weighs only .37 pounds, and is designed to operate from −300 to +160°F, with pressures to 750 psi. ■ Since only corrosion-resistant steels are used in contact with the fluid, it is suitable for a variety of uses, and the entire valve is completely enclosed and hermetically sealed. ■ Typical of the precision hydraulic, pneumatic and gas-actuated controls designed and manufactured by Weston, this new valve is available as a standard model, or can be modified to suit an individual need. Call or write for technical bulletin #P-101.

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CIRCLE 136 ON READER SERVICE CARD

Auxiliary Processors Speed Large-Scale Computing System

Sylvania's big 9400 data processing system communicates with its input and output equipment by way of small-scale auxiliary processors connected to its main data transfer bus. Each input-output processor—there can be four —can control up to 64 input or output devices. The purpose is efficient usage of central processor and main memory. In the 9400, all four in-out processors running at once use only a small portion of available main memory time. The result is high over-all system speed suitable for on-line execution of complex analytical and control operations. Very fast real-time control is possible through buffers that communicate directly with core memory at high speed.

HOWARD I. COHEN,
Sylvania Electric Products Co.

Most digital data processing systems are arranged so that the central processor control unit and high speed memory must be time shared with the needs of relatively slow input and output devices. As a result, the very expensive high speed core memory that gives a computer its high potential is in use less than 10 percent of the computer running time in the average installation. And having to interrupt the main problem program to run input or output equipment subroutines through the central control unit slows down problem solution and makes it more difficult to predict program running time. Thus, low efficiency in the use of high speed components has often made an otherwise very fast computer impractical for an on-line or a real time problem.

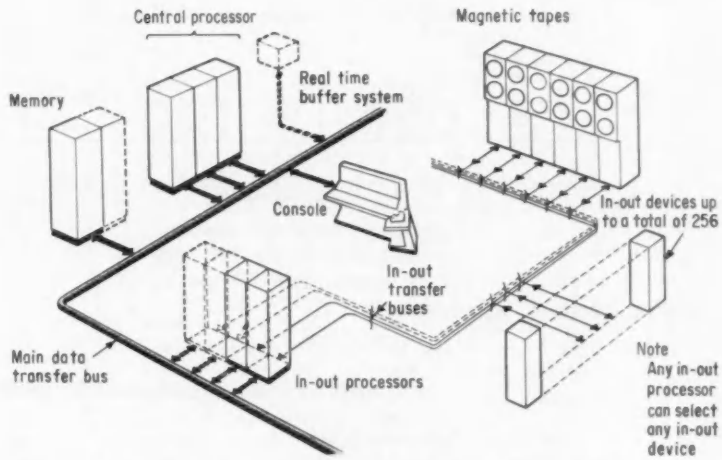


FIG. 1. Sylvania 9400 data processing system uses fast data transfer bus to connect central processor and main memory to in-out processors. Data rate on the main bus ranges up to 1½ million words per min. Binary words of 37 bits are transferred in parallel; basic memory access time is 4 microsec. Data transfer on in-out buses takes place at maximum rate of input or output device.

The system concept used in the Sylvania 9400 large scale data processing system attacks this efficiency problem head-on. The 9400 uses up to four independent input-output processors that contain their own control units for running the special program routines for input or output equipment independently of the central processor. The in-out processors represent a new concept of input-output control within the framework of a large general-purpose data processing system.

The in-out processors connect directly to the main data transfer bus by which the central processor communicates with all other units of the computer at high speed, see Figure 1. Data and control transfers on the main bus are made parallel-by-bit, a 37-bit binary word at a time (36 bits plus sign). Multiple in-out processors are truly parallel, because each can select and control any one of the input or output devices, of which there can be up to 64 per processor or 256 on a full 9400 system.

The input-output system operates on data in convenient 6-bit character groups (Fieldata) that per-

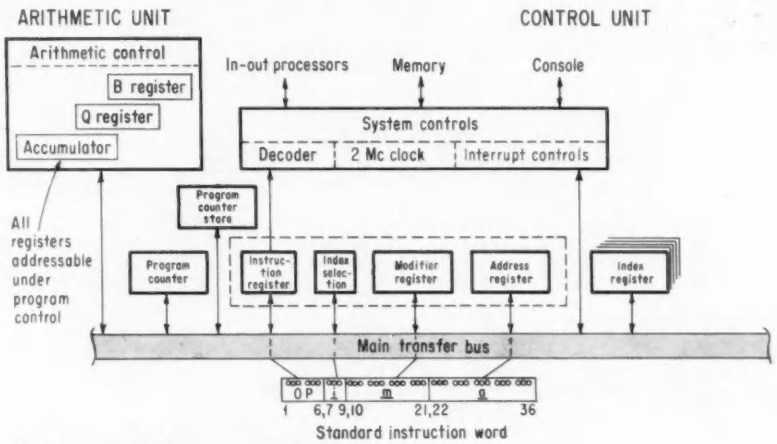
mit easy translation to and from alphanumeric codes like Hollerith (punched card), and Baudot (punched tape). The in-out processors automatically assemble characters into words, words into blocks, and blocks into files.

Blocks or files can vary in length from a single word to the total capacity of any particular storage device.

Figure 2 shows the organization of the central processor control unit for comparison with the in-out processor in Figure 3. The instruction words shown in both figures are always stored in the core memory, whether they be from the 9400's central instruction repertoire, the input-output instruction repertoire, or the running problem program. The main 9400 instruction repertoire includes 58 instructions for transfer and control, conditional jumps, logic and editing, priority interrupt, fixed and floating point arithmetic, and single input-output instructions. Also, there are 14 special input-output instruction words for the in-out processors which contain microprogram-type control bits that greatly expand the basic order list.

Computer word transfers between the main memory and the central or in-out processors take place in 4 microsec, while the character transfer rate to and from an input device is adjusted to the maximum speed of the device by the in-out processor.

FIG. 2. Central processor of 9400 can be divided into two units: arithmetic and control. Arithmetic unit has its own control, gets its data from memory under control of main control unit. Single-address instruction words which control each operation come to control unit from core memory via main transfer bus.



9400 central processor . . .

. . . and unique input-output processor

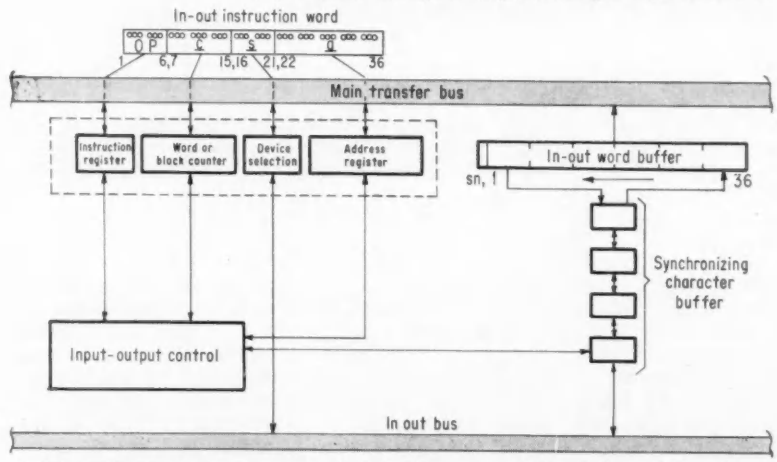


FIG. 3. An input-output processor includes its own control unit, lower left, and can follow programs stored in a specified portion of main memory. Buffers at right synchronize slow data rates on in-out bus with high rates on main bus. In-out processor operates on translation and editing programs necessary for transferring data to or from various input or output devices, while central processor proceeds with main program.

Operation of the in-out processor

The central processor provides for two different modes of in-out processor operation. The first is called the single instruction mode—an input or output instruction in the main program is decoded by the central processor and executed by an in-out processor. The second mode, called the order sequence mode, makes it possible for the programmer to store a sequence of orders in the high speed memory to be decoded and executed by the in-out processors independently of the central processor.

A special instruction called "start order sequence" initiates the order sequence mode. When a start order sequence instruction occurs in the main program, it is decoded by the central processor and sent to the in-out processor to be used, which selects the input or output device to be controlled, and specifies the address in the main memory that is the starting point for the sequence of orders to be carried out by the in-out processor. The in-out processor then executes the first of this series of orders using the specified

device while the central processor proceeds with the main program. Figure 4 illustrates the steps in the order sequence mode.

The in-out processor can pace itself to execute the instructions in the order sequence as the device is ready to accept the orders. An instruction to search a magnetic tape for a particular entry, for example, can take an indeterminate time, so the in-out processor can be instructed to wait until the tape entry is located. The order sequence mode provides a special device status sensing order activated when the 9400 must share input or output devices with other systems.

Another order in the order sequence family allows data from various portions of the memory (that is, not all contained in the same set of sequential locations) to be transferred to an output device as a single block. This order is called "gather write". The reverse order, called "scatter read", permits reading data from an input device and systematically storing it into strategic locations in the memory rather than in sequential locations. This technique greatly facilitates sorting and merging operations by minimizing the time devoted to moving data from one part of memory to another.

Still another order provides a way to insert key words into files for their easy identification. And in reverse, the key words can be recognized in the files in the normal process of searching to simplify retrieval of filed data. Special "end-of-block" and "end-of-file" codes can be recorded on magnetic tape to initiate control functions.

Thus, the programmer may prepare a set of instructions for each of the in-out processors which will then be executed in parallel and simultaneously with central processor operations on the main program. The in-out processors operate simultaneously and share the memory with the central processor. Almost the total memory access time is available for the central processor. An order sequence may be either conditionally or automatically terminated by appropriate control bits in an order, or the programmer may write an "end sequence" order.

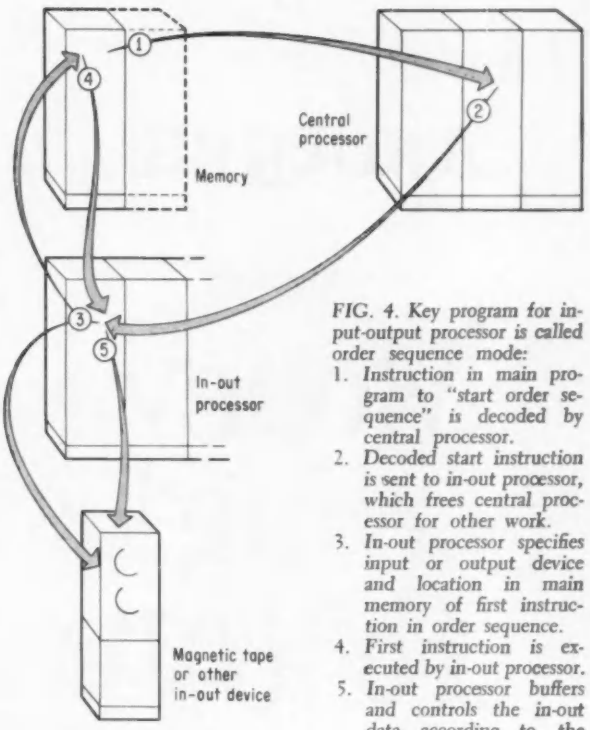


FIG. 4. Key program for input-output processor is called order sequence mode:
1. *Instruction in main program to "start order sequence" is decoded by central processor.*
2. *Decoded start instruction is sent to in-out processor, which frees central processor for other work.*
3. *In-out processor specifies input or output device and location in main memory of first instruction in order sequence.*
4. *First instruction is executed by in-out processor.*
5. *In-out processor buffers and controls the in-out data according to the order sequence program.*

Real time inputs for high speed processes

An optional "real time" input-output system can be connected directly to the main data transfer bus, so that data can be transferred between the main memory and real time channels at rates as high as 1½ million words per min. Thus, the real time system permits the 9400 to communicate with and control processes in which very fast changes can occur. With a real time system, for example, the 9400 can communicate directly with other computers and with a large variety of digital communication equipment. And the fast communication enables the computer to digest data and calculate the best or safest conditions for process parameters controlled by its output lines in time for the process to respond to its orders.

To make the most effective use of the high processing speeds in real time buffering, central processing, and input-output processing, the 9400 has an elaborate repertoire of program interrupt instructions wired in. Certain special program conditions such as arrival of data at a real time input channel, detection of certain control characters on magnetic or paper tape, detection of an end-of-file code, or arithmetic overflow or underflow, can cause the central processor program to be interrupted automatically and transferred to a standard memory location. The programmer can then provide instructions to start a corrective or diagnostic subroutine to handle the special case. This technique permits the programmer to take many liberties because he needs only to anticipate the occurrence of interruptions and plan the resulting actions, and does not have to provide instructions to look to see if interruptions are necessary. These features simplify programming while permitting any sophistication desired.

On the other hand, sixteen electronic switches are provided through which the programmer may interrogate any of a large variety of functions (device status, overflow alarms, process emergencies, etc.) and thence extend program control. These electronic switches have associated manual switches on the operator's console, and may also be used to make day-to-day or even run-to-run changes in the computer operation. Thus, the interrupt features are also balanced in the 9400 between letting the computer anticipate for the programmer many of the control functions that would normally be expected and leaving the programmer free to act on these functions by interrogation.

The Sylvania 9400 uses many data verification and error detecting techniques, plus alarms to verify correct operation of all peripheral devices. The modular concept of equipment organization makes system expansion easy as the need arises.

ANOTHER

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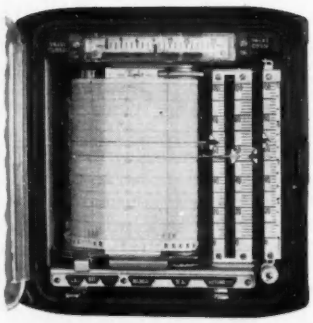

SINGLE-CASE CASCADE

A complete Cascade System in one recorder case—in half the normal panel board area, thus conserving control room space—means substantial savings. You need only one case, one chart drive, one panel cut-out.

The single case cascade idea was pioneered by Taylor in the TRANSCOPE* Recorder. Here are some of its features:

All switches in one case. The operator performs all start-up and shut-down operations in one recorder. There are no external switches or relays—the cascade set-point is always in view.

All functions in one case. Master and secondary variables are continuously recorded. Controller outputs, as well as set points, are continuously indicated . . . and with more indications than with any other instruments.

Unique "Petroleum Switching". True cascade control from secondary; or control from master only, direct to the valve without comparing gages.

Front-of-panel control settings permit faster, easier adjustments—the operator can watch results because record is continuous.

Stays on automatic control while the recorder is removed. No process interruption for instrument service or adjustments.

* * *

Single case cascade is another example of Taylor engineering ingenuity that saves you money . . . gives you better process control. See your Taylor Field Engineer, or write for **Bulletin 98286.** *Taylor Instrument Companies, Rochester, N.Y., and Toronto, Ontario.*

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MEAN ACCURACY FIRST

Industrial Robot Learns New Jobs With Ease

MAURICE J. DUNNE
Consolidated Controls Corp.

A new moving arm robot called Unimate, Figure 1, is well suited to perform jobs that are repetitive but temporary. Any operator can program Unimate in little more time than it takes to run through the desired task once. First, the operator attaches teaching equipment with pushbutton switches for each possible direction of motion to the robot's arm, wrist, and hand. Then he leads the machine through the task by finger pressure on the switches, Figure 2, pressing a record button at each stopping point. These positions are entered in sequence in a memory which later directs the robot from point to point.

Up to 200 positions can be stored in a "Dynastat" memory drum, Figure 3. The surface of this drum contains 16,000 magnetically retentive segments or bits which can be polarized in either of two directions. The segments are arranged in 200 parallel rows around the periphery of the drum, 80 segments to a row. Each command is recorded as an 80-bit Gray code number containing all information required to control the machine's motions and operate external equipment and the hand clamps or tool. Since the drum read heads respond to flux polarity and are unaffected by the rate of change of flux intensity, the drum does not have to rotate to present its readings. It remains stationary at a given row while each command is carried out. Continuous head output is available for comparison without the need for amplifiers or intermediate storage registers. As each step is completed, the drum is indexed to the next command.

Unimate's arm can telescope from 3 to 7 ft at up to 30 in. per sec. It can sweep through a horizontal arc of 220 deg and a vertical arc of 60 deg at up to 110 deg per sec. The wrist at the end of the arm can bend through 220 deg and rotate 180 deg, also up to 110 deg per sec. All five motions are powered by a self-contained hydraulic supply. Each motion, independent of the others, is directly coupled to a shaft position-to-digital encoder which defines a Gray code number for each position in the traverse. The resolution of each motion was designed to give 0.05-in. definition of the position of an object held at full arm extension.

During programming the total Gray code from all encoders is transferred to the drum write heads each time the record button is pressed. When the machine is switched to the "repeat" mode, Figure 4, the drum steps to home position with the read heads over the code command representing the starting point. The command code from the drum and the present position code from the shaft encoder are sent to a special comparator which digitally determines the sign and magnitude of the error between the two Gray code inputs without conversion to an intermediate code. The difference signal operates the hydraulic control valve to cause a motion that closes out the difference. When all differences have been zeroed, the control system indexes the drum to the next step, and the process is repeated.

To operate at maximum speed, controlled velocity and deceleration rates prevent mechanical overstress, overshoot, and hunting. While servoing, the logic system initiates movement in the proper direction at maximum speed. Then as the error magnitude signals change, the actuation velocity is reduced at the highest possible deceleration rate consistent with shortest traverse time and prevention of overshoot. The logic system is composed entirely of resistance coupled dc transistor switching gates. This system proved to be no more costly than a time-shared arithmetic unit with a high repetition rate clock.

Since command recording consists of impressing a particular polarity on the drum bits, a new program can

Mechanical Arm

FIG. 1. Unimate robot performing a two-stage forge pressing operation.

How it Learns

FIG. 2. The author teaches Unimate to pick up 16-lb steel cylinders.

Where it Remembers

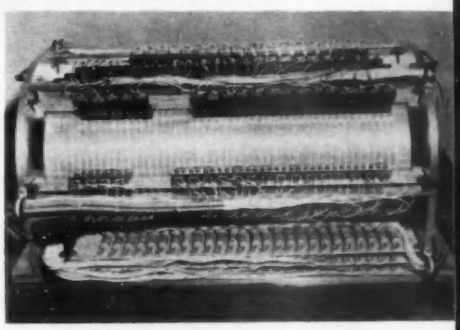
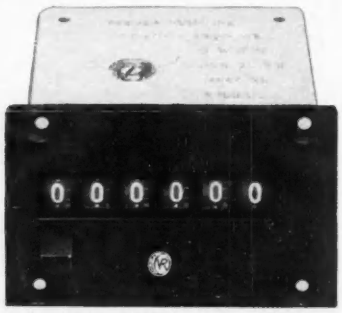


FIG. 3. Drum with 16,000 magnetic segments stores 200 arm positions.

Keep your seat while you keep your eye on 20 operations—and more...with Veeder-Root's High-Speed Magnetic Counter. At a glance, a quick review of plant production from one central location... complete visual control without legwork or guesswork. It's easy with Veeder-Root remote readout counters on the job. Compact in design, easy to install, these versatile counters are finding their way into more and more new machinery designs...are being added to existing equipment to streamline and centralize plant control. For more information write: Electrical Section, Veeder-Root Incorporated, Hartford 2, Conn. **count on...Veeder-Root**



This electrically actuated Veeder-Root counter, Series 1591, reports machine output directly from factory to your office... operates on regular lighting circuit, dry cells, storage battery or other power supplies.

Will Unimate Get a Chance to Prove Itself?

The makers of Unimate have turned up 100 different kinds of operations which they say robots could perform more efficiently than human labor. They estimate that there are 40,000 places now in existence in industry where Unimate could cut costs and improve production. On the other hand, two Detroit automobile company spokesmen questioned by McGraw-Hill News winced at the price—$25,000 with annual maintenance estimated at $1,300. One said his company would want any such machine to pay for itself in 18 months, whereas Consolidated Controls figures payoff time as more like five years, based on working two shifts.

The other company representative's philosophy on industrial robots is that an acceptable one for general purpose work must either cost significantly less than human labor or be able to do things people can't do. He said no machine he has seen measures up to these specifications, and Unimate didn't sound like it would either. In his opinion, Unimate is a step in the direction of practical robots and will be bought in small quantities to see what it will do, but it will not lead to wholesale replacement of manpower in repetitive jobs. Ed.

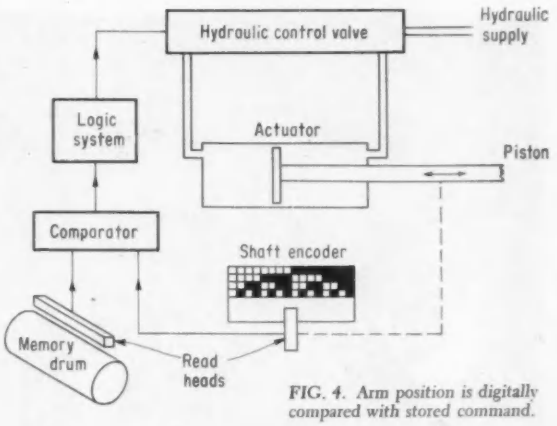


FIG. 4. Arm position is digitally compared with stored command.

be put directly over the old with no need for erasing. During teaching, a counter on the control panel shows the drum position corresponding to the steps in the sequence. If a correction is required, the drum can be advanced to the step to be corrected and a single new command recorded without disturbing the rest of the program.

The memory also controls isolated 20-amp contacts that can be used to control press operation, welding equipment, paint spray guns, etc. Unimate can be programmed to wait for an external signal, such as opening of a press die or arrival of material at a loading position. Time delays can be initiated, and all or any part of an operation can be programmed to run at slow speed to avoid spilling liquids, upsetting partially assembled work pieces, or handling loads up to 75 lbs without strain (maximum load at normal operating speeds is 25 lbs.

Hand clamping is pneumatically operated so that the grip can be adjusted for fragile or heavy objects by varying the pressure. Maximum clamping force at the end of 4-in. fingers is 300 lbs.

Unimate weighs 2,700 lbs and can be moved from job to job with a fork lift truck. The self-contained arm requires only the connection of electrical power. Some applications foreseen for Unimate are material loading and transfer, packaging, welding, paint spraying, and assembly jobs such as nut running and part insertion.

Finding Thermistor Coefficients at Nonstandard Temperatures

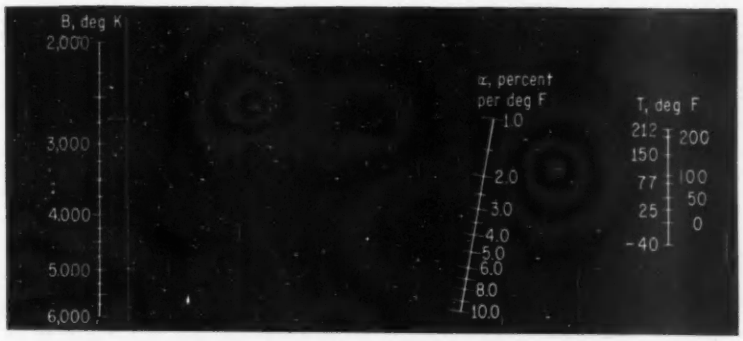
LESLIE R. AXELROD
Powers Regulator Co.

To use thermistors one has to know something about their temperature coefficient of resistance, α. Unfortunately most manufacturers' data sheets give α only at 25 deg C (77 deg F), while the thermistors themselves are often used at other temperatures. For a given thermistor, α is not constant but varies with temperature in accordance with the equation

$$\alpha = -100\,B/T^2$$

where α = temperature coefficient, percent per deg C.
B = material constant, deg K.
T = thermistor temperature, deg K.

The accompanying alignment chart solves this equation, but the scales have been adjusted to give temperature in deg F and α in percent per deg F. The chart can be used in two ways, as illustrated by the following examples.



EXAMPLE 1. A VECO 43R1 thermistor has an α of -2.44 percent per deg F at 77 deg F. What is α at 150 deg F?

Solution:
1. Lay a straightedge from 77 on the T scale across 2.44 on the α scale. Mark its intersection with the B scale.
2. Lay the straightedge from the intersection mark on the B scale to 150 on the T scale.
3. Read the new value of $\alpha(-1.8$ percent per deg F) at the intersection of the straightedge and the α scale.

EXAMPLE 2. A Ferroxcube B8/320/08P/150K thermistor has a B of 5,450 deg K. What is α at 77 deg F?

Solution:
1. Lay a straightedge from 77 on the T scale to 5,450 on the B scale.
2. Read the value of $\alpha(-3.5$ percent per deg F) at the intersection of the straightedge and the α scale.

REFERENCE

PROPERTIES AND USES OF THERMISTORS, J. A. Becker, C. B. Green, and G. L. Pearson, "Transactions of the AIEE", Vol. 65, 1946, pp. 711-725.

But RBM "Customer-izes" This Quality Basic Relay for Low-Cost Solutions of Many Control Problems!

The RBM 98000 Series AC or DC Relay is capably performing such a variety of tasks you might think you were seeing double. Truth is, there are so many different contact forms, ratings and terminal variations . . . all regular production items at RBM . . . that the 98000 Series has been "customer-ized" to fulfill almost every conceivable requirement. RBM's vast background of application engineering frequently can serve you with design shortcuts like this . . . and at low cost when delivered in volume.

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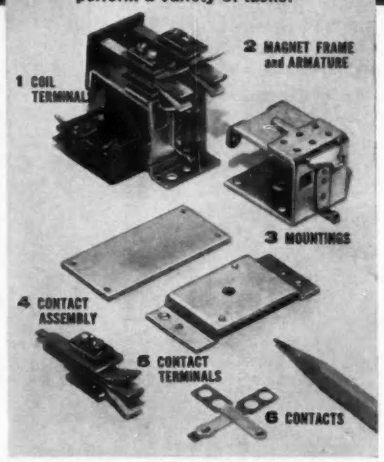
For engineering help on the most efficient and low cost solution of any control problem, consult your local RBM Application Engineer or send specifications direct.

Request Bulletin 1060 for complete information on RBM General Purpose Relays.

These component production variations perform a variety of tasks.



These are exclusive high quality design features of the RBM 98000:

Many are listed by U/L File No. E12139 or No. E22381.

1. Varieties of coil terminals available; solder, quick-connect or leadwires.
2. Simplified magnet frame and armature assembly provides efficient, positive action.
3. Variety of mountings available.
4. Pressfit contact pile-up eliminates drift; assures contact stability.
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Also available is the RBM 97000 Series Relay, providing additional coil power or greater sensitivity.

CONTROLLING RBM QUALITY THE FUTURE

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Electromechanical Transducer Measures Pressure Ratio Directly

R. H. MYERS
Vought Electronics Div.
Chance Vought Corp.

Modern turbojet aircraft must operate efficiently at a wide range of speeds and altitudes, and air inlet duct design is a serious problem. If more air is swallowed than the engine needs, back pressure is created; if not enough air is supplied to the engine, thrust suffers. For any Mach number there is a mass flow in the duct that will provide maximum efficiency. One solution is to provide another exit path in the form of doors just ahead of the engine. The total flow in the duct is then measured continuously and compared with a reference which is a function of the Mach number of the airframe. The error signal actuates the doors.

Design of such an automatic bypass system posed two primary problems; determining the dynamics of the duct (dynamics determined analytically were verified by wind tunnel tests), and obtaining reliable measuring devices with suitable dynamic characteristics. Since mass flow is hard to measure, it was decided to monitor the static to total pressure ratio, P_s/P_t, instead; this ratio is a function of mass flow. The reference would be derived from a similar measurement in the free stream outside the aircraft.

A survey of the available pressure ratio sensing devices revealed that they were not accurate enough and that little was known about their dynamic behavior. The first arrangement tried is diagrammed in Figure 1. The free stream transducer is a conventional force balance servo measuring device which drives a cam directly from the fulcrum position or aircraft P_s/P_t. The cam operates a potentiometer, and its output voltage positions the fulcrum of the duct transducer. This is another conventional balance, modified to improve its dynamic response. By operating on the position of the beam nonlinearly with a force proportional to the static pressure in the duct, the position of the beam is made proportional to duct P_s/P_t. Beam position controls the core of a linear motion variable transformer in the output circuit. Preliminary tests showed a definite error limiting problem which prevented rapid operation of the doors, as well as a nonlinear output with static pressure.

Replacing the duct transducer with an electromechanical device, Figures 2 and 3—developed by the GE Flight Control Laboratory under contract to Chance Vought—improved both dynamic performance and linearity. Here, the duct pressure ratio positions a rocker arm which varies the magnetic circuit of an E-shaped transformer core. The center winding of the transformer is connected across the free stream unit pot; the two other windings have opposite polarities and are in series with the output terminals. Any change in free stream P_s/P_t moves the potentiometer wiper and produces an error signal which operates the bypass door motors until duct P_s/P_t and the rocker position are such that the error signal is reduced to zero.

FIRST MODEL . . .

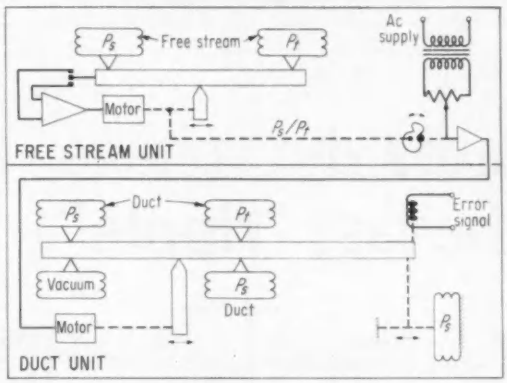

FIG. 1.

IMPROVED VERSION

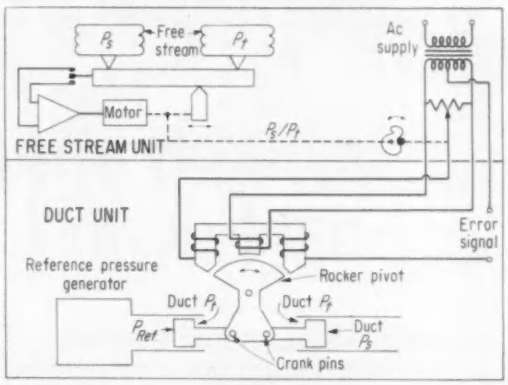

FIG. 2.

Fig. 1. Conventional pressure ratio sensor limited performance.

Fig. 2. This novel transducer improved linearity and response.

Fig. 3. New duct transducer with cover off to show rocker arm and transformer.

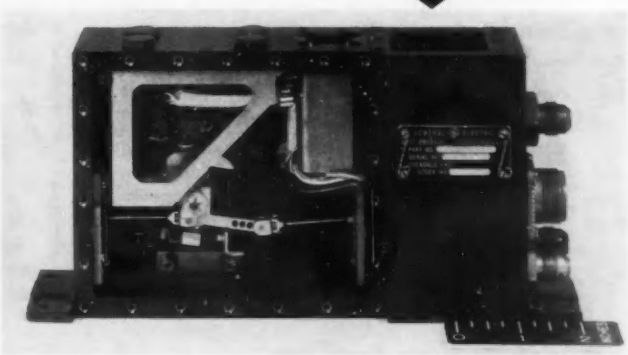

FIG. 3

new SOLA transistorized d-c supply...

reliably regulates d-c voltage – right down to the last **"ripple"!**

New highly sensitive SOLA "CVQ" provides transistor-regulated d-c output ideal for computers and other *voltage-sensitive equipment*. Response to voltage change is so rapid the CVQ even attenuates 120-cycle ripple! Yet, with it all, this new d-c supply introduces a revolutionary circuit simplicity — providing significant savings in sizes . . . more watts per dollar!

CVQ combines exclusive transistorized shunt regulation with SOLA's inherently self-protecting, static-magnetic transformer . . . easily meets the most taxing demands of dynamic loading. Voltage holds in spite of widely fluctuating loads. The result is longer equipment life, more trouble-free operation. Contact our area representative for complete specifications and prices. Or write today for literature on CVQ.

- Standard models available at 5, 6, 10 and 12 volts d-c (100-130/181-235/200-260 volt input).
- Output regulated within ±0.04% for line voltage variations ±15%; 0.2% static-load regulation, 0 to full load.
- Excellent transient response.
- Inherent protection against output over-voltage safeguards both supply components and external circuitry.
- Short-circuit proof design.
- Compact mechanical layout — only 12¼ x 5¼ x 19"

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Relays and Counters Compute Timber Yard Throughput

J. MISRAHI
New Electronic Products,
London, England

A special purpose electronic computer installed at the Phoenix Timber Co.'s main yard at Rainham, Essex, measures the length and width of each piece of hardwood timber entering the yard. Measurements are displayed on visual indicators and printed out on a paper tape. Simultaneously, the surface area of each piece is calculated and accumulated in the computer store. The printer records the area total on demand.

The machine's throughput of 3,000 cu ft of timber a day more than doubles the yard's capacity. The previous limit of 800-1,000 cu ft a day was determined by the rate at which human measurers could operate. Traditionally, clerks measured the timber lengths and widths visually and mentally computed the area to an accuracy of about 1 percent. Accuracy of the automatic measurer is better than 0.1 percent.

Hardwood timber is discharged from ships onto the quay in rough bundles of differing widths and lengths. A conveyor fork-lifts the timber vertically, feeding it piece by piece onto a 7-ft measuring conveyor, Figure 1. As each piece arrives on the measuring conveyor, powered cross-feed rollers drive it against a datum board which provides the zero length reference point. Dogs on the conveyor carry the timber length forward until it reaches a row of 50 fingers attached to individual microswitches. These microswitches are spaced every 6 in. to cover timber lengths up to 25 ft with normal timber yard accuracy of plus or minus 3 in. The number of microswitches actuated is thus a measure of timber length.

While the microswitches are actuated, the board intercepts a photocell light beam, and this initiates computer action, Figure 2. Timing pulses are generated by two 3½-in. diam, 500-line moiré fringe discs. Coupled to the conveyor drive through main and variable ratio gear boxes, the discs generate pulses at a rate proportional to conveyor speed. The variable gearbox is set to give 3,000 pps at the normal conveyor speed of 6 ips. These pulses are divided down in two sets of decimal trochrotrons (counter tubes); the output of the second set is 50 phase-displaced 60 pps trains.

One 60 pps output signal feeds a 3-decade trochrotron counter through a gate and pulse shaper. The gate opens when the photocell beam is interrupted and this starts the measurement. Each pulse received by the counter is equivalent to $\frac{1}{10}$ in. of timber width, irrespective of conveyor speed variations. The pulses are counted until the timber clears the photocell beam and the gate is closed. The counter then indicates the width of the board.

The area of each piece of timber is

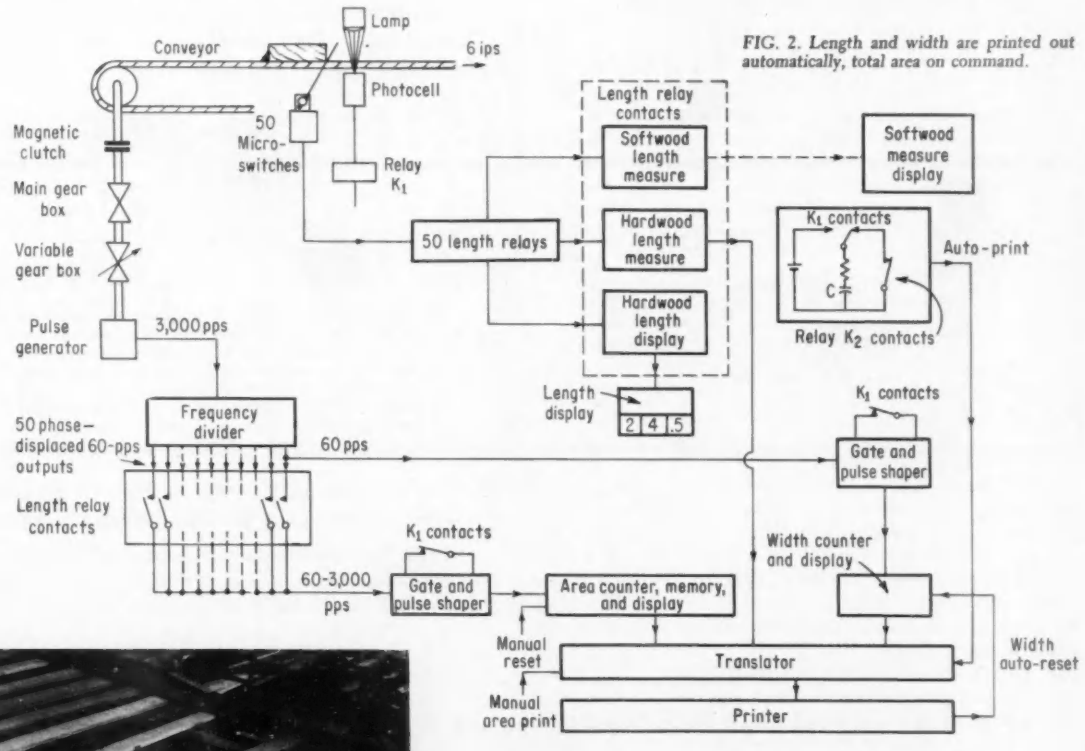


FIG. 2. Length and width are printed out automatically, total area on command.

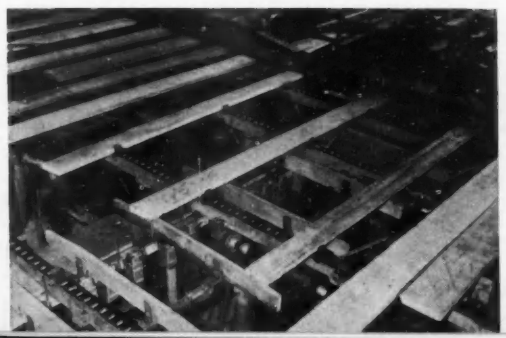
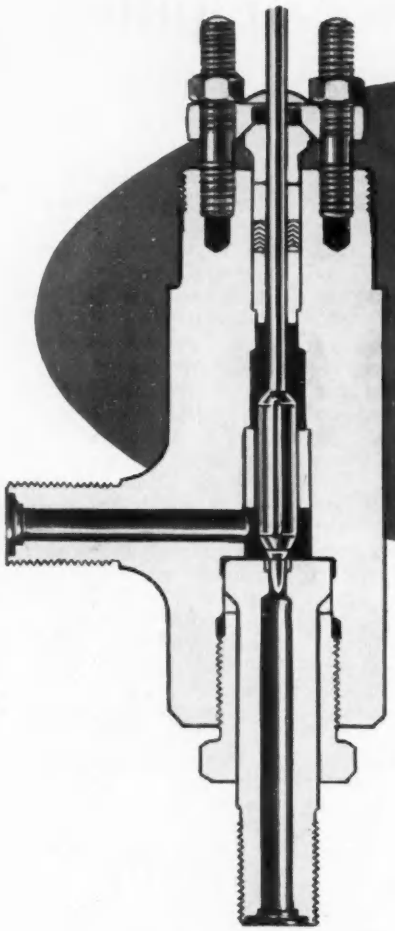


FIG. 1. Boards pass over microswitch fingers and cut photocell beam.

see FISHER for your

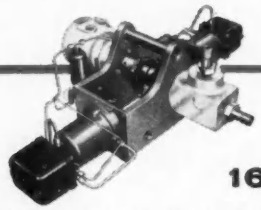
Ultra High Pressure Jobs



When you encounter pressures up to 60,000 psi at 500°F., Fisher can help by designing and producing a high pressure control valve for your specific need ● Typical is the Design "C" Body, a hammer forged unit for pressures ranging from 5,000 to 35,000 psi ● When required, body forging is heat treated and hardened for added structural strength ● Can be produced in Monel, stainless steel, Titanium, and other alloys. Available in a wide variety of high pressure end connections.

470-C

TYPE 470-C utilizes the popular 470 P.O.P. mounted on the hammer forged "C" body. Has received wide acceptance in processing of ammonia and urea. Handles pressures up to 45,000 psi.



16531

TYPE 16531 is a specially designed high pressure control valve for polyethylene let down service. Hammer forged body activated by two powerful 480 P.O.P. actuators which can take independent signals for automatic operation or from manual loading station. Either electrical or pneumatic valve position transmitter.

For complete information on Fisher high pressure control valves send for Bulletin E-500-A.

Fisher Governor Company, Marshalltown, Iowa. Plants in Woodstock, Ont., Rochester, England. Butterfly Valve Division: Continental Equipment Co., Coraopolis, Pa.

If it flows through pipe anywhere in the world ...chances are it's controlled by.....

FISHER® Controls SINCE 1880

calculated digitally by repetitive addition of the width measurement, until the number of operations equals the piece length. To achieve this, the 50 outputs from the divider circuits feed a common gate via individual relay contacts actuated by the length measuring microswitches. For every foot of timber length two relays close, connecting two of the outputs to an area counting unit. As the timber moves forward, two phase-displaced 60 pps signals feed the counter. After 1 in. of forward movement the counter has received 120 pulses and registers the area of a 12 x 1 in. piece as 12 sq in. For longer boards additional relays close, increasing the number of pulse paths to the gate.

As each piece of timber clears the photocell beam, relay K_1 closes the width and area gates to stop the counting and discharges capacitor C through secondary relay K_2 to initiate printout. Solenoid translator circuits coupled to the length and width counters actuate a printer operated in parallel to register the length and width of the board. The end of print signal from the printer clears the width counter immediately after printout. When the microswitches are finally released, all the relays are cleared and ready for the next piece of timber. The area counter accumulates the total area of all pieces until printout is demanded.

Softwood classification differs in that only the total number of pieces having lengths in multiples of 1 ft are required for each batch of timber, width and thickness remaining constant for the batch. Additional contacts on the relays energized by the length measuring microswitches operate electromagnetic counters that indicate the number of pieces of each different length and a batch counter to indicate total pieces in the batch. On switchover to softwood, the area and width counters and printer are switched off, and an electromagnetic clutch disengages the pulse generator.

Conventionally a human checker adjusts the final length and area totals to allow for faults such as knots or splits in the wood. Future development at the Phoenix yard will allow a less skilled operator to feed quality information to the computer, which will weight final totals according to timber grade. A lever with settings for top, medium, and low quality will be coupled to the datum board on the measuring conveyor. In the position for medium quality, each foot of timber registers a foot on the computer. For top quality knot-free timber, the lever will alter the datum to register in excess of a foot for each foot length that passes. For poor quality timber, extra length will be added to make up for blemishes.

Machinist Dial-Programs Own Control Tapes

F. LAURENCE GOSNELL Wang Laboratories, Inc.

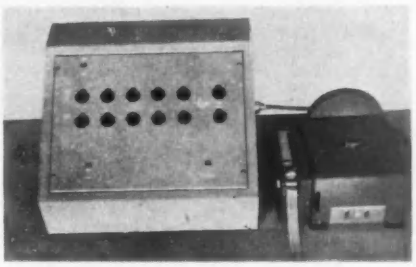


FIG. 1. Dials on the console panel set dimensions and feed rates.

Numerical control has been kept out of small job and model shops by the lack of methods personnel who know programming techniques and of clerical help who can operate a typewriter-tape punch. But with the small console and standard Friden punch shown in Figure 1, anyone, including the machinist who is going to use the equipment, can do programming and prepare tapes. The "tape preparator" is furnished as an accessory to the Weditrol numerical control systems manufactured by Wang Laboratories.

Weditrol tapes in a two-axis system use 16-line blocks of holes to specify x and y dimensions and feed rates for each tool operation. Lines 1-5 give the x dimension to 0.001 in.; line 6 indicates one of four feed rates, typically from 1¼ to 10 in. per min, or rapid traverse. Lines 7-11 are for the y dimension, and line 12 gives the y feed rate.

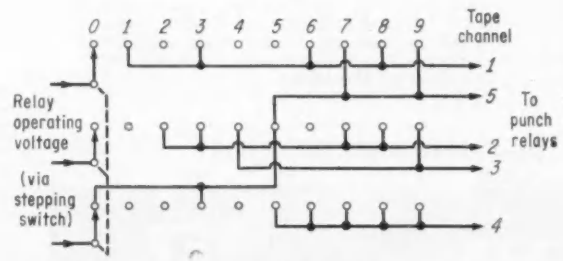


FIG. 2. Rotary switch provides binary coded decimal dimensions and a parity check.

Lines 13 and 14 are spares, available to operate auxiliary contacts where needed, and lines 15 and 16 are for reset and end-of-block signals. Each line has eight holes or channels: 1-4 for binary-coded decimal dimensions and feedrate code numbers; channel 5 for a parity check; channels 6 and 7 for spares, and channel 8 for the end-of-block signal in line 16.

The operator specifies all numerical information for one block with 12 rotary switches on the console. Five switches set in the digits of the x dimensions, one the x feedrate code number, five the y dimension, and one the y feedrate. A toggle switch specifies automatic reset at the end of the block. This is used in "picture frame" mailing to turn corners automatically and complete the operation. In drilling, reset is automatic anyway since the rising quill trips a microswitch and advances the tape to the next block of instructions.

After setting in the block of information and checking it visually, the operator presses a record button. This energizes a stepping switch that sends current through the contacts of the first rotary switch to relays that punch the required holes in row 1 on the tape. Each rotary switch has three poles, which are wired, Figure 2, to convert the decimal setting into four binary outputs plus a parity check. The stepping switch then advances to the next rotary switch, the tape is advanced, and row 2 is punched. This process continues at a speed of about 15 lines per sec until the complete block has been punched. The operator then resets the dials on the console for the next block of instructions.

Transitron

SILICON CONTROLLED RECTIFIERS

augmenting the industry's broadest line

With the addition of the 50-Amp Silicon Controlled Rectifier, Transitron now offers the industry the broadest line of Controlled Rectifiers available on the market today.

Research and development efforts during the past year have already produced an impressive array of types which include the following series:

TSW31S SERIES (TO-18 package).....operating current range to 200mA
TCR251 SERIES (TO-5 package).....operating current range to 1 amp
2N1595 SERIES (TO-5 package).....operating current range to 1 amp
2N1600 SERIES (7/16" hex package)...operating current range to 3 amps
TCR505 SERIES (7/16" hex package)...operating current range to 5 amps
TCR510 SERIES (11/16" hex package) operating current range to 10 amps
TCR520 SERIES (11/16" hex package) operating current range to 20 amps

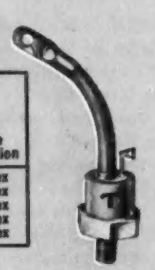
NOW AVAILABLE — NEW 50-AMP CONTROLLED RECTIFIER

The latest addition to the Transitron line — the 50 Amp Silicon Controlled Rectifier — is a three-terminal, four-layer device designed to control very large load currents with small gate current signals. A mechanically rugged and electrically stable device, the new Controlled Rectifier is provided in the 1⅛" hex base stud-mounted package and is hermetically sealed. Wherever high power handling ability is required, the 50-Amp Silicon Controlled Rectifier will find wide application ranging from frequency changing to welding control.

TCR550 SERIES (1⅛" hex package) operating current range to 50 amps

Type	Min. Peak Reverse Volt. and Min. Forward Breakover Volt. (volts)	Max. Average Forward Current at 90°C case (amps)	Package Configuration
TCR4050	400	50	1⅛" hex
TCR3050	300	50	1⅛" hex
TCR2050	200	50	1⅛" hex
TCR1050	100	50	1⅛" hex
TCR550	50	50	1⅛" hex

Requires 50mA to turn on 50 Amp



For information on any or all of Transitron's line of Controlled Rectifiers, call or write today for Bulletin TE-1356.

WHY BIAS CONTROLLED RECTIFIERS?

THE BIASING OF SILICON CONTROLLED RECTIFIERS AND SWITCHES

Pioneering in *new* application techniques, Transitron application engineers have assembled information which demonstrates how "gate biasing" will improve the circuit reliability of the SCR. This informative booklet, entitled "The Biasing of Silicon Controlled Rectifiers and Switches," deals individually with *each* of Transitron's Controlled Rectifiers and Switches. It is an indispensable aid to the design engineer seeking *longer life* and *greater stability* in higher temperature applications . . . It's yours for the asking.

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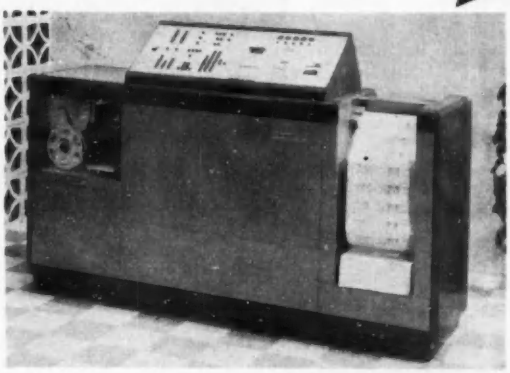
NEW PRODUCTS

PRODUCTION DATA GATHERING SYSTEM handles forms machine and man can read.

At right a shop employee is entering production information in the Stanrecorder, an employee activity data gathering unit that accepts input from embossed plastic plates (for personnel identification and for operation and transaction data), prepunched tab cards (for accounting information), an optional numerical keyboard (for variable information), and a time clock (for time and date). This easily moved, self-contained unit reads all information in less than a second and prints it on a two-part form in both Arabic numerals and machine language. One copy is available for employee reading—if desired—or both copies can be refolded in a locked compartment.

The margin-punched continuous pages can be converted to a form suitable for data processing machine input by manual key punching, below right, or, if the volume of data warrants, the forms may be read by the Stanomatic Reader-Translator, below left. This solid-state electronic unit converts the data to punched tape or cards or to magnetic tape at speeds up to 300 forms per min. A self-checking feature is built in.

Workman prepares forms that . . .



. . . or by electronic translator.

. . . are readable by eye . . .

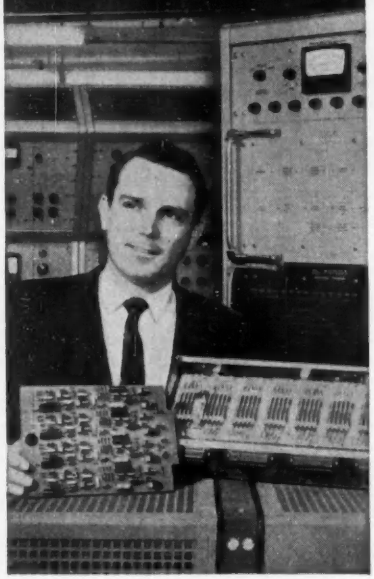
An optional counting device can be added to the input unit to be attached to a machine for automatic recording of unit production. Because of the recording unit's flexibility, however, a great variety of functions can be monitored. For instance, the unit can be used for inventory control, with a printed receipt being made for each item inventoried. It can also handle personnel transfers, machine breakdowns and maintenance, tool control reporting, scrap reports, and, in short, anything that happens within a plant.

As an aid to users considering the Stanrecorder system, the manufacturer will make available a feasibility package, consisting of an input unit and a supply of two-part forms and embossed plastic cards. The prospective user can then try out the unit in his plant or office under varying conditions and at low cost. Purchase price of the Stanrecorder is about $2,900, depending on optional features.—The Standard Register Co., Dayton, Ohio.

Circle No. 309 on reply card

NEW

MB Automatic Spectrum Equalizer



- *Speeds Up Random Vibration Testing*
- *Eliminates Costly Set-Up Time*

MB's New Automatic Spectrum Equalizer provides automatic compensation of "random motion" system. Saves time and money in environmental testing of missile components and systems. Simply set desired spectrum shape on graphic panel in terms of power density in db, and turn the level control. The fully automatic control system assures conformity between desired and actual spectra. Tests can be rerun at a later date with assurance of identical spectral content.

Other features include:

- High accuracy; employs 80 filters, each 25 cps wide, covering frequency range 15 cps to 2000 cps.
- Wide dynamic control range
- High stability; better than .008%/°C.
- Low distortion; less than 1.5%
- Special read-out to permit rapid analysis

For more information, send for Bulletin 129.

MB ELECTRONICS

A DIVISION OF TEXTRON ELECTRONICS, INC.
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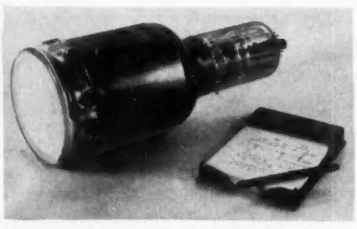
NEW PRODUCTS

DATA HANDLING & DISPLAY

CHECKS NC TAPES

The Model 570 produces an X-Y plot of digital data on a special recorder to check magnetic tapes prepared for numerically controlled equipment. The plotter is completely automatic and compatible with most digital computers. Zero positioning, scale factor adjustments, and curve and symbol identification are controlled by the computer programmer. The plotted charts or graphs are reproducible by transmitted light processes. Continuous curve plotting is at 2 ips with no curve shape restrictions, but 30 sec of plotting can be recorded by the computer in 1 sec. Point plotting is 175 points per min with arbitrary symbol choices. Magnetic tapes with linear density of 200 bits per in. prepared on tape units similar to IBM 727 or 729 are acceptable. System including recorder is priced at $24,500.—California Computer Products, Inc., Downey, Calif.

Circle No. 310 on reply card



SELECTIVE ERASE TUBE

With this new display storage tube it is possible to erase information selectively and simultaneously display stored and nonstored information. High resolution light or dark traces are possible. The Multi-Mode Tonotron uses a dual effects target employing bombardment - induced conductivity effects in addition to secondary emission. Display can consist of cursors, digital codes, or even maps. High contrast displays can also be had by writing with the erase beam while the viewing screen is in full brightness; the resulting picture is a dark trace image. Prime applications include air traffic control radar, sonar, weather radar, and satellite mapping.—Hughes Aircraft Co., Vacuum Tube Products Div., Oceanside, Calif.

Circle No. 311 on reply card

COMPACT RECORDER

Only 8½ in. high, this compact multipoint strip chart recorder is designed to mount in a standard relay rack. The Model M11A will scan and measure 2-12 input sources at the rate of 5 sec per point, although other rates are available. Calibrated chart width is 11 in. Range changes are easily accomplished using plug-in modules. Changeover from basic 12-point to 6, 4, 3, or 2-point unit is done by changing print head and jumper plug. Price: $1,300.—Westronics, Inc., Ft. Worth, Tex.

Circle No. 312 on reply card

FIBER OPTIC CRT

A miniature precision cathode ray tube with a face panel made of an array of fiber optic light pipes allows direct high speed optical printing on film and other light sensitive materials. Light pipes are coded on their vacuum side with a phosphor that is excited by electron beams from the tube's electron gun. Digital deflection voltages can produce a digital code on the tube's face. The fiber optic light pipes conduct light from the phosphor to the outside, without dispersion, where recording can be done without supplementary optics. This direct recording, along with the light pipes' light transmission efficiency, accounts for a 50 times improvement in recording speeds over conventional CRT techniques. The E1E11 tube is ca-

THOMAS A.

EDISON

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guards critical temperatures for Con Edison

Con Edison's power generating station in Astoria, Long Island, one of the largest of its kind in the world, supplies one-eighth of the power consumed by New York City's millions. An installation as vital as this naturally requires the utmost protection to insure efficient, uninterrupted operation—around the clock, around the calendar. And this is where Thomas A. Edison's OMNIGUARD system provides such an important contribution.

The bearings of Con Edison's auxiliary equipment, ranging from main boiler feed pumps to coal pulverizing mills, are monitored by Thomas A. Edison resistance temperature detectors which are connected to Omniguard monitors located in the main control room. If any one of the 200-plus bearings monitored begin to overheat, an alarm is sounded instantly, the trouble area is identified on the Omniguard panels, and prompt corrective action is taken. Thanks to Omniguard, trouble is detected *before* damage can be done—which not only increases bearing life but slashes Con Edison's over-all maintenance costs as well.

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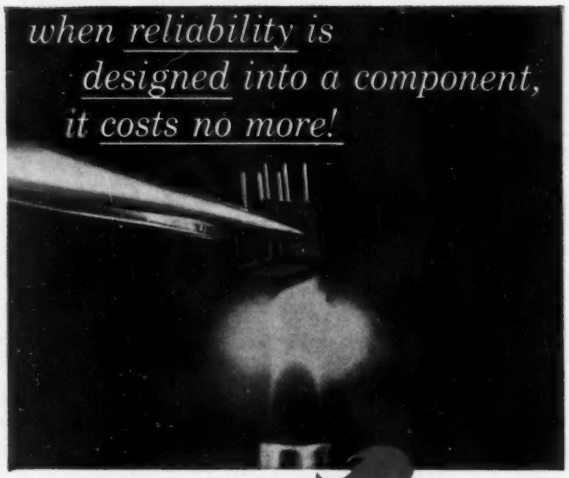

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TRANSFORMERS

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MAGNETIC CORE COMPONENTS
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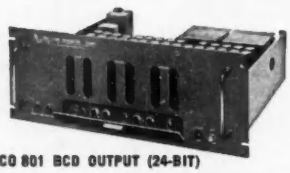
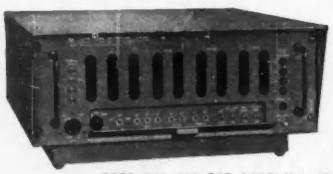
TIME TEAM

HOW EECO'S ALL-STAR LINEUP OF TIME CODE GENERATORS WINS ON EVERY POINT

Look at these unparalleled advantages offered by EECO Time Code Generators! Frequency stability, 3 parts in 10^8, based on extremely stable crystal oscillator. 100% plug-in circuits to keep generator working for you day in and day out. Emitter-follower low-impedance outputs for long-distance transmission. Wider operating-temperature stability. Operable from aircraft power. Provision for external frequency standard. Auxiliary pulse rates.



EECO 801 BCD OUTPUT (24-BIT)



EECO 810 100 PPS CODE (36-BIT)

Model Number	Serial Code Format	Time Indication	Code Frame Length (SEC)	Code Scan Rates (PPS)	Code Carrier Frequency (CPS)	Price (f.o.b. Santa Ana)
EECO 801	24-Bit, 24-hour, BCD	hr. min. sec.	1	25, 50, 100	1000	$7500
EECO 802	17-Bit, 24-hour, Binary (Eglin AFB)	hr. min. sec.	1	20, 100	1000	$7000
	13-Bit, 24-hour, Binary (Patrick AFB)	hr. min. ¼ min.	15	1	1000	
EECO 802M1	17-Bit, 24-hour, Binary (Atlantic Missile Range)	hr. min. sec.	1	100	1000	$7000
EECO 802M2	17-Bit, 24-hour, Binary (Atlantic Missile Range)	hr. min. sec.	1	20, 100	1000	$7000
			20	1		
EECO 803	20-Bit, 24-hour, BCD	hr. min. sec.	1	25	250	$7500
EECO 804	20-Bit, 24-hour, BCD	hr. min. sec.	1	25	100 w/1000	$7925
EECO 810	36-Bit, 365-day, BCD	day, hour min., sec.	1	100	1000	$10,100
EECO 810M1	23-Bit, 365-day, BCD (IRIG Member C Format Modified)		60	2	1000	$10,100

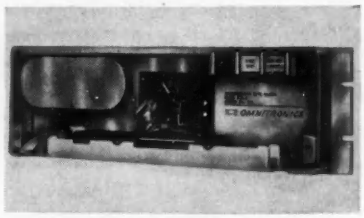
SEND FOR TIME CODE GENERATOR FILE 301

Electronic Engineering Company of California
1601 East Chestnut Avenue • Santa Ana, California • Kimberly 7-5501 • TWX: S ANA 5263
EE 1-27

NEW PRODUCTS

pable of recording a complete digital description in as little as 50 millisec. Coded matrix is 32 x 32 elements for 1,024 information bits. Price: $550. —Display Devices Dept., Litton Industries, San Carlos, Calif.

Circle No. 313 on reply card



CHOPPED LIGHT READER

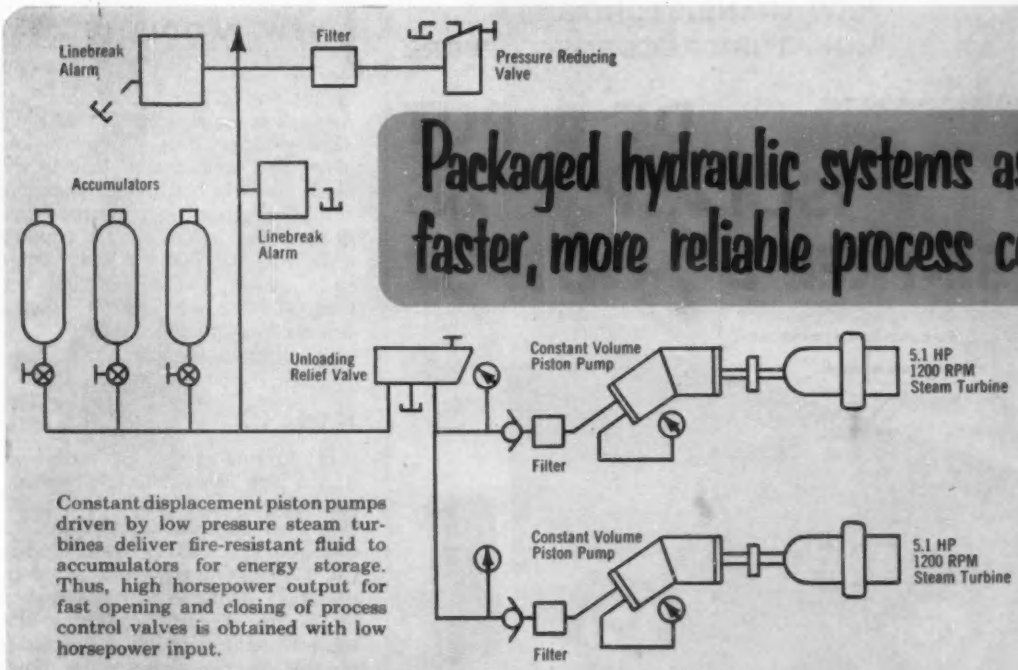
Reliable paper tape reading is offered by this new photoelectric reader that operates on a unique principle of chopped reflected light. Use of a light chopper wheel and ac coupled amplifiers allows better operation because of superior stability of these amplifiers over dc types. Better signal to noise ratio is possible when reading some transluscent tapes because reflected light is used. The PTR-7 uses silicon solar cells and will read standard $\frac{11}{16}$, $\frac{7}{8}$, or 1 in., up to 8-channel, of strip or continuous loop tape. Speeds of 10, 30, 75, or 100 ips are selectable. Fast starting and stopping time is another feature. Price: under $3,000. — Omnitronics, Inc., Sub. of Borg-Warner Corp., Philadelphia, Pa.

Circle No. 314 on reply card

LIGHT TAPE PRINTER

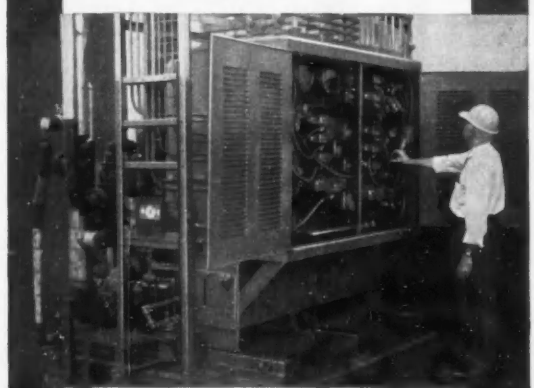
This small tape printer weighs only 11 lb and uses a nonradiating low voltage electronic printing technique and plug-in circuit boards to achieve high reliability and easy servicing. Either conventional or special codes can be accepted. Maximum printing rate is 120 wpm. A matrix block

Packaged hydraulic systems assure faster, more reliable process control



Constant displacement piston pumps driven by low pressure steam turbines deliver fire-resistant fluid to accumulators for energy storage. Thus, high horsepower output for fast opening and closing of process control valves is obtained with low horsepower input.

Control console and power unit form electro-hydraulic system for controlling automatic heat treatment cycle. Physical layout provides optimum circuit efficiency, ease of servicing, and good appearance.



This power package includes all hydraulic pumps and valves for complete control of automatic cyclic operation of process in a butadiene plant.

Fast and precisely controlled motions, having the high reliability demanded by modern processing, are inherent characteristics of hydraulics. In addition, these advantages are obtained at low cost, for you can cover your full range of operations—from valve control to power transmission—with standard Vickers components. Your engineers enjoy unlimited design flexibility through a choice of electric, electronic, pneumatic and manual signals to control the hydraulic pumps, motors, cylinders, and variable speed drives.

Vickers complete packaged systems are ready to go into service upon arrival in your plant, since they are thoroughly pretested before shipment. They are properly designed and built to give maximum service life with little downtime, thus helping to keep your plant on stream.

Get more information on the job being done by Vickers packaged hydraulic systems in chemical, petrochemical, petroleum refining, and other processing industries by writing today for Bulletin I5802, "Packaged Hydraulic Systems for Process Control."

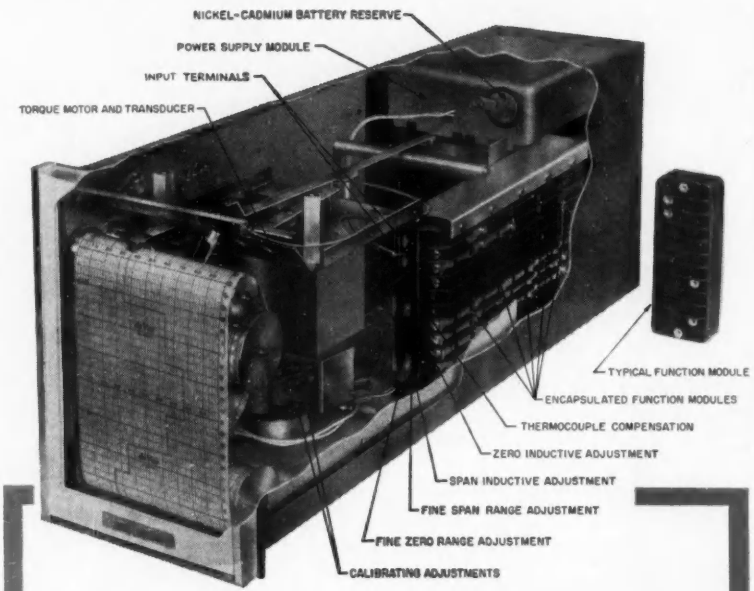
VICKERS INCORPORATED
DIVISION SPERRY RAND CORPORATION
ADMINISTRATIVE and ENGINEERING CENTER
Department 1606 • Detroit 32, Michigan

9138

GENERAL KINETICS
CONTROL SYSTEMS
DE VAR

NEW TRANSISTORIZED
MINIATURE RECORDER OFFERS

DC INPUT ISOLATION AND NOISE-FREE DC OUTPUT



The unique DE VAR potentiometer/receiver recorder is particularly suited for Strain-Gage Transducers, Thermocouples and Resistance Bulb Elements. The isolated input circuit rejects high common-mode noise without resorting to input balancing. The DC output signal is sufficiently noise-free to feed data loggers or computers. In addition, a low noise, high frequency carrier signal is available for drift-free operation of controllers and alarms.

- Exclusive inductive zero and span adjustment — continuously variable from 0-5 mv to 0-50 mv.
- Complete solid state circuitry — including unique transistor chopper.
- Battery reserve — eliminates costly down time.
- Full scale rectilinear writing — with 1, 2, or 3 pens.

Our Technical Bulletin R-301 describes the most advanced miniature recorder now available —

Write today

DE VAR SYSTEMS INC.
494 GLENBROOK ROAD
GLENBROOK, CONNECTICUT

A DIVISION OF GENERAL KINETICS CORPORATION

NEW PRODUCTS

contains seven rows of five 0.010-in. diam printing dots. Input is amplified and applied selectively to the block, and the pattern of energized dots is impressed on a sensitized tape to form the letters. Power required is 28 vdc, but the unit can operate on a 12-volt mobile electrical system. — Goodyear Aircraft Corp., Arizona Div., Phoenix, Ariz.

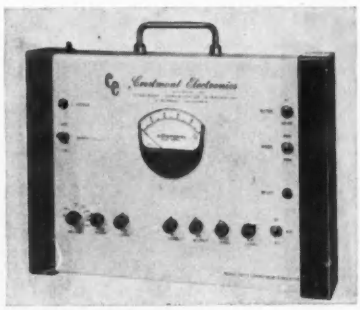
Circle No. 315 on reply card

PLUS . . .

(316) Printed motors are used in a $2,520 high speed (300 lines per sec) **photoelectric tape reader** now available from **Photocircuits Corp.**, Glen Cove, N. Y. . . . (317) **North Electric Co.**, Galion, Ohio, has introduced an **analog to digital converter** designed for on-line digital telemetering and control applications. . . . (318) A versatile instrument priced at $490 available from **Bytrex Corp.**, Newton, Mass., provides continuous **meter** indication of pressure, torque, force, weight, or flow when used with a strain gage transducer.

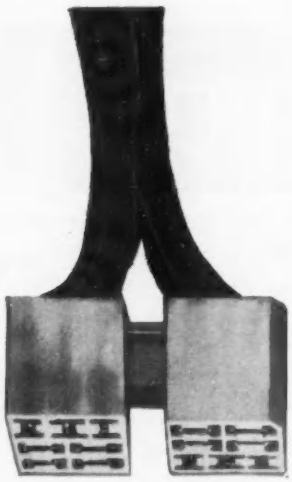
Circle Nos. 316, 317, or 318 on reply card

RESEARCH, TEST & DEVELOPMENT

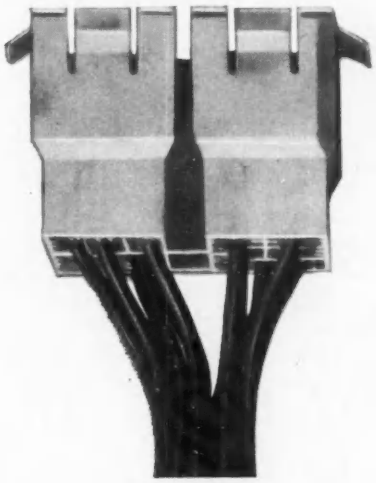


PORTABLE TEST SETS

Shown above is a commutator simulator that accurately simulates commutator output, permitting checkout of telemetering ground station equipment without depleting commutator life. Unit generates PAM or PDM repetitive pulse frames; any number of pulses can be framed to operate at any repetitive rate. Matching decommutator unit checks the status of a commutator without tying up



This **AMPin-cert*** connector line **GIVES YOU BOTH** economical assembly, easy maintenance **WITH ALL 3**



AMP-LOK®

- self-locking friction contacts create positive wiping action
- low millivolt drop
- 3, 4, 6, 9 and 12 circuits
- wire ranges #22-#18, #20-#15 and #18-#16 AWG
- nylon housing has "snap-in" wings for through panel use
- keying plug prevents mismatching caps in side-by-side mounting

AMPEEZ*

- 7, 14 and 20 circuit
- insertion/extraction force of 2-5 lbs. per contact
- "Tab-Gap Lok" prevents contact spread
- fits wire size range #18-#14 AWG
- amperage rating 20-25
- nylon housing polarized for perfect mating
- mounts flush—only .125" projects from panel front

FASTIN-FASTON*

- 1, 2, 6 and 8 circuits
- contacts are self-locking in housing
- fully tested for millivolt drop
- nylon or cycolac housings polarized to prevent circuit errors
- wire insulation support for vibration resistance
- full wire size #18-#14 AWG

* Trademark

This line of AMPin-cert Connectors gives you minimum insertion and withdrawal forces, maximum amperage ratings, resistance to vibration, corrosion and environmental factors . . . everything to assure lower assembly costs, rugged performance and simplified maintenance. Check these features and see how they fit your design plans. Any additional information you may need will be sent on request.

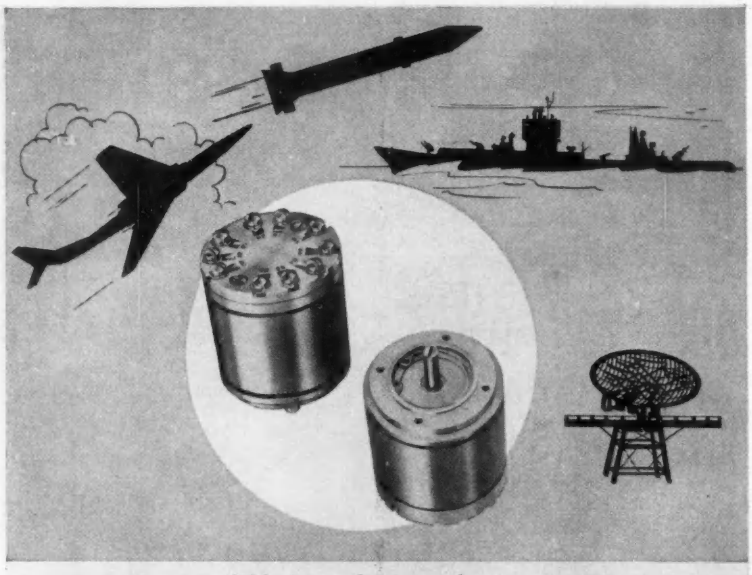
AMP INCORPORATED

GENERAL OFFICES: HARRISBURG, PENNSYLVANIA

AMP products and engineering assistance are available through subsidiary companies in: Australia • Canada • England • France • Holland • Italy • Japan • Mexico • West Germany

CIRCLE 157 ON READER SERVICE CARD 157

ENGINEERING
REPORT
ON BENDIX COMPONENTS



Now available in production volume:

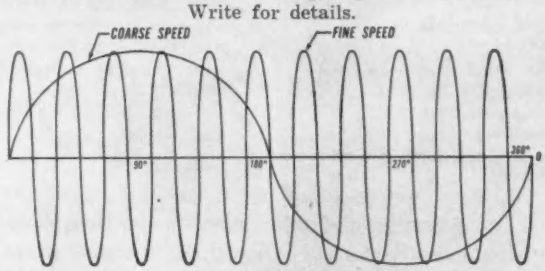
BENDIX AUTOSYN® SYNCHROS AND SYSTEMS with 30-SECOND ACCURACY

The Bendix two-speed Autosyn synchro was developed to meet the need for accurate data transmission with maximum system simplicity. Two electrical outputs are produced from the Autosyn single shaft, eliminating both inaccuracies of two-speed gearing and the installation and maintenance costs of an additional unit.

Autosyn units can be supplied with leads or terminal boards. Units can be used back-to-back or can be coupled with mechanical two-speed transmitters or control transformers. They measure only 2.34" in length by 1.75" in diameter.

Other features: **Accuracy unaffected by thermal or mechanical stress—Adaptability to gyro pick-off—Elimination of gear error of mechanical two-speed system—High signal-to-null ratio.**

Write for details.



EXAMPLES OF APPLICATIONS: Fire Control Systems—Navigation Computers—Inertial Guidance Systems—Radar Antenna Tracking

Eclipse-Pioneer Division
Teterboro, N. J.

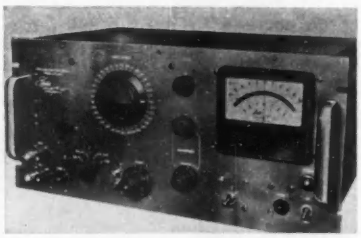
THE Bendix CORPORATION

District Offices: Burbank, and San Francisco, Calif.; Seattle, Wash.; Dayton, Ohio; and Washington, D. C.
Export Sales & Service: Bendix International, 205 E. 42nd St., New York 17, N. Y.

NEW PRODUCTS

data reduction facilities. It receives PAM or PDM pulses in repetitive frames and presents an analog of the information in any desired pulse. Unit features high input impedance for direct connection to the commutator or to receiver's discriminated output. Both instruments are self-contained and available with 30, 45, 60, or 90 channels. Accuracy is said to be within 1 percent. Ac power for optional internal battery supply may be used. Each unit is priced at $1,200. —Crestmont Electronics Div., Crestmont Consolidated Corp., Burbank, Calif.

Circle No. 319 on reply card



TESTS RESOLVERS

This resolver function bridge tests conformance of a computing resolver's output to the ideal sine or cosine function. Difference, expressed as a percentage, is displayed directly on a panel meter. No more than 0.002 percent error is introduced into the test by the device. Internal phase sensitive detection circuits respond only to the fundamental in-phase components of resolver output.

Characteristics

Range: 360 deg
Quadrature rejection: 50 to 1
Third harmonic rejection: −40 db
Resolver phase shift acceptable: −50 to +20 deg
Resolver outputs acceptable: 5-50 volts
Price: $2,000
—Theta Instrument Corp., Saddle Brook, N. J.

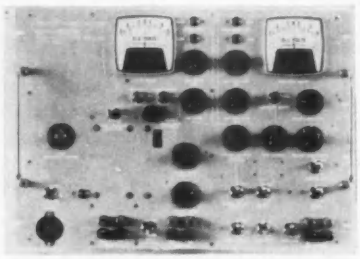
Circle No. 320 on reply card

INTERVAL COUNTER

The Model 5275A time interval counter provides precise digital measurements of very short time intervals between events that can be represented by electrical pulses. Intervals can be measured from 10 millimicro-

sec to 0.1 sec. The resolution to 10 millimicrosec is achieved over the full range. Counted frequency is 100 Mcps, obtained from an external 1-Mcps source. Included as standard equipment are remote reset, trigger terminals, and a four-line bed electrical output. Price: $4,500.—Hewlett-Packard Co., Palo Alto, Calif.

Circle No. 321 on reply card



SERVOSYSTEM CHECKER

Designed for checkout of acrospace vehicle servo control systems in the field or during production, the Series VSA dynamic servoanalyzers combine the functions of signal generation, dynamic response analysis, and data presentation. Frequency response test requires only the time for a single cycle of each test frequency plus ½ sec. Choice of readouts includes visual or electrical and analog or digital. Operation may be manual or automatic. —Giannini Controls Corp., Duarte, Calif.

Circle No. 322 on reply card

MONITORS PROBES

This new AL-4T Magne-Alarm monitors temperature reported by precalibrated thermistor probes to as close as 0.1 deg F. Use of thermistor sensors eliminates reference junctions and provides greater sensitivity to closer limits. Bridge voltage is furnished by the Magne-Alarm unit to provide a self-contained system. All solid state, the unit uses a bistable magnetic amplifier as high gain amplifier, limit sensor, and output driver to achieve reliability, ruggedness, and stability. Off-normal conditions are indicated visually and audibly on local or remote indicators. Price: $125-200 per channel.—San Diego Scientific Corp., San Diego, Calif.

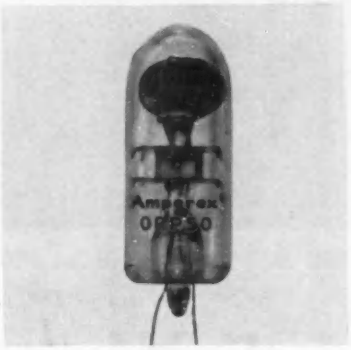
Circle No. 323 on reply card

PLUS . . .

(324) Now offered by **Perkin-Elmer Corp.**, Norwalk, Conn., is a Size 9 Vernistat **ac potentiometer** that is reduced in size from previous models and will sell for one-half the price. . . . (325) The Model 900 Series Servodyne all **electronic servoanalyzer** from **Remando, Inc.**, Santa Monica, Calif., provides direct reading phase and amplitude measurements vs frequency for electronic, electromechanical, and mechanical servosystems. . . . (326) Priced at only $69.95, the Primer-Scope Mark I is a compact 3-in., rectangular screen **oscilloscope** for light laboratory and service use now available from **Waterman Products Co.**, Philadelphia, Pa.

Circle No. 324, 325, or 326 on reply card

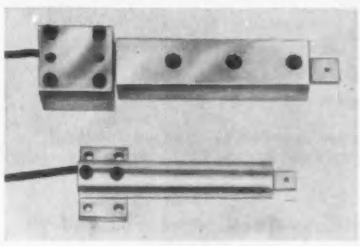
PRIMARY ELEMENTS & TRANSDUCERS



TOP AND SIDE SENSITIVE

This new light sensitive cadmium sulfide cell is sensitive at both the top and side. The double sensitivity is permitted by positioning the CdS area at a 45-deg angle. Hermetically sealed in rugged glass, the ORP 50 is suitable for flame control, automatic counting, and level and density control. The cell measures 0.63 in. in diam by 1.42 in.—Amperex Electric Corp., Semiconductor and Special Purpose Tube Div., Hicksville, N.Y.

Circle No. 327 on reply card



LARGE OUTPUT LOAD CELLS

These rugged load cells provide outputs of 1 volt at capacity load.

ENGINEERING REPORT ON OTHER BENDIX COMPONENT PACKAGES

NEW 2-SPEED "PANCAKE" SYNCHRO TRANSMITTER

Resists stresses and temperature extremes

This compact, two-speed "pancake" synchro transmitter consistently exhibits an accuracy within thirty seconds of arc under dimensional stresses and wide temperature variations. The same order of accuracy is maintained when the transmitter is used back-to-back with a conventional two-speed control transformer. The synchros are operable from −55°C. to +200°C. They are logical replacements for existing mechanical two-speed transmitters. Their bantam weight (5 oz.) and small size (2.685" O.D. x 1.002" I.D. x 0.562" thick) suits them ideally to vertical gyro gimbals and other assemblies where size and weight are critical factors. Write for complete information.

Manufacturers of

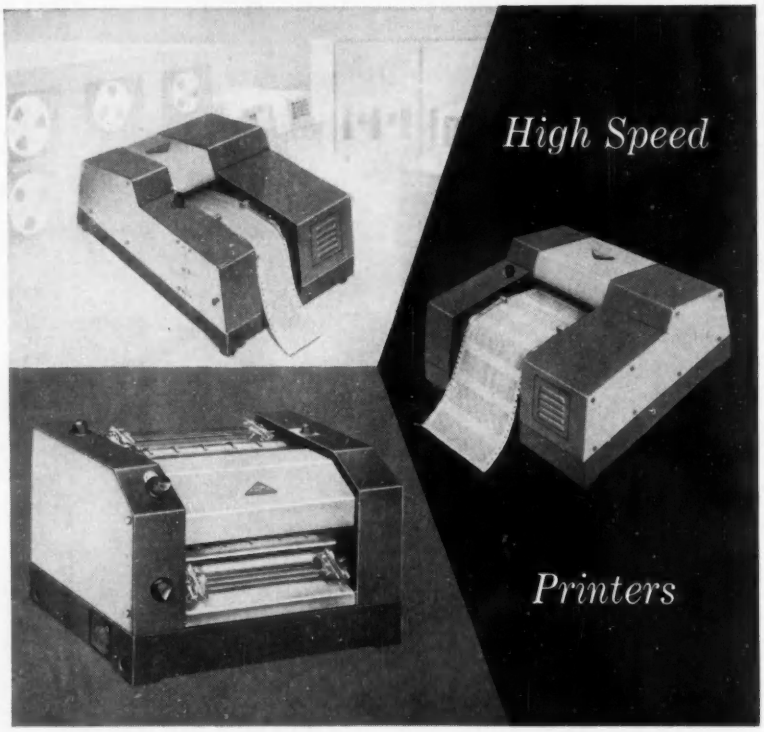
GYROS • ROTATING COMPONENTS
RADAR DEVICES • INSTRUMENTATION
PACKAGED COMPONENTS

Eclipse-Pioneer Division

The Bendix Corporation

Teterboro, N. J.

Completely Redesigned



by

ANELEX®

. . . of course

Data processing systems builders* . . . and users expect this from Anelex. And for good reason. Most new developments associated with high speed line printing for EDP systems . . . even to high speed printing using machine-recognizable characters . . . have orginated with Anelex.

The highly specialized skills acquired by Anelex engineers in the creative development of advanced systems enables them to best design mechanical, electro-mechanical and electronic out-put equipment. In all probability the techniques required for your particular system have already been accomplished. This group, with their extensive knowledge and experience, is available for a discussion of your requirements.

***Anelex High Speed Printers are supplied as standard equipment by 22 major computer and systems builders.**

ANELEX

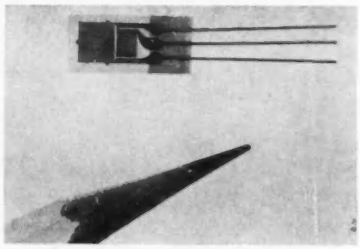
Anelex printers will be displayed in Booth 93-94 Western Joint Computer Conference.

ANELEX CORPORATION
150 CAUSEWAY ST., BOSTON 14, MASS.

NEW PRODUCTS

Wheatstone bridge circuit using semiconductor strain sensitive elements senses resistance change proportional to applied load or deflection. Resolution is limited only by the readout instrument, and repeatability is better than 0.1 percent. Temperature compensation is on the order of 0.1 percent per deg F for thermal coefficient of sensitivity and 0.005 percent per deg F for thermal zero shift. Load ranges from $\pm\frac{1}{2}$ to $\pm$100 lb are available. Price: $275. — Kulite-Bytrex Corp., Newton, Mass.

Circle No. 328 on reply card



CALCULATING STRAIN GAGE

This newly announced bonded resistance-foil strain gage has a built-in computation circuit that solves general strain to stress equations automatically. The stress-strain gage provides electrical signals proportional to the stress or strain at user's option by using two axial strain sensing elements oriented 90 deg apart. One element measures conventional strain; the other rejects the axial component of strain caused by stress in a transverse direction. Combined elements then respond to component of strain produced by stress in the axial direction. Through simple switching, three measurements can be made: 1) strain along principal sensing axis, 2) strain along transverse axis, and 3) stress along principal sensing axis. Gage is available with Poisson's ratio for steel or aluminum. Price (in quantities of five): $9 each.—Electronics & Instrument Div., Baldwin-Lima-Hamilton Corp., Waltham, Mass.

Circle No. 329 on reply card

PLUS . . .

(330) The Refractosyn, available from **H H Controls Co.**, Burlington, Mass., is a **differential refractometer** for fluid composition control that is priced under $1,000. . . . (331) **Servo-Tek**

NEW BARTON 273 PNEUMATIC TRANSMITTER MEETS MORE APPLICATION REQUIREMENTS THAN ANY OTHER TRANSMITTER

The Barton 273 offers the widest differential pressure ranges (0-8″ w.c. to 0-400 psi), the highest safe working pressures (to 10,000 psi), and the widest variety of housing materials (aluminum, brass, steel, 316 stainless steel). It's compact, weighing up to less than ½ the weight of other units. It has adjustable suppression up to 80% of DP range, and adjustable span. A non-bleed relay minimizes air consumption. It doesn't shift zero on overrange. It's unaffected by normal piping stress. In every respect, the Barton 273 is the most significant advance in pneumatic transmitters in the past decade. There's a lot more you should know about it—for complete data write

BARTON

INSTRUMENT CORPORATION, 580 MONTEREY PASS ROAD, MONTEREY PARK, CALIFORNIA.

CIRCLE 161 ON READER SERVICE CARD 161

Chromel*-Alumel

THERMOCOUPLE ALLOYS

a complete family of time-tested materials developed especially to meet your particular application requirements

Remarkable alloys, Chromel and Alumel—in many more ways than one. For although they were discovered over 50 years ago, they're still new today. As new as the newest need for accurate temperature measurement—still the only base metal thermocouple alloys known that have proved their reliability over the entire range of temperatures from —300° up to +2300°F. What's more, in addition to the original standard materials guaranteed to register true temperature-emf values within ±4°F. from −300° up to +530°F. and within ±0.75% from +531°F. up to maximum recommended operating temperature, they are now available in the following special grades to meet the exacting requirements of your particular applications:

Specification 3G-345

A special grade of Chromel wire developed expressly for use in reducing or corrosive environments—with temperatures in the critical operating range between 1600° and 1900°F.

Specification 3G-196

A special grade of Alumel wire possessing outstanding resistance to oxidation at high temperatures. Developed especially for use in such atmosphere applications operating above 1600°F.

Specification 3G-115

Chromel and Alumel thermocouple grade material of guaranteed emf that is specially processed to close resistance limits. Typical uses include measuring exhaust temperatures of jet aircraft engines.

Specification 3G-170

Specially processed Chromel and Alumel thermocouple grade wires matched to closer than standard emf tolerances for applications requiring accuracy within ±5°F. at temperatures above 1000°F.

Specification 3G-178

Special research grade Chromel and Alumel thermocouple wires for precision laboratory work. Accuracy is guaranteed within ±2°F. from —300° up to +530°F., and ± ⅜% from 531° to 2300°F.

Specification 3G-187

A special grade of Chromel and Alumel thermocouple wire developed for use in nuclear reactor applications. Has good stability of emf during long time exposure at temperatures up to 1000°F.

Specification 3G-161

Guaranteed millivoltage Chromel and Alumel thermocouple grade wire specially processed to provide a smooth, bright, semi-hard material properly tempered for cold-heading operations.

Specification 3G-213

Guaranteed millivoltage Chromel and Alumel thermocouple grade alloys supplied in the form of hot rolled rod and cold drawn wire specially processed to obtain proper temper for machining.

Specification 3G-220

A special grade of Chromel and Alumel wire processed for use in sheathed thermocouple units. Available with emf guaranteed to within standard tolerances and also to ½ standard limits.

Complete New Catalog-Manual contains detailed information on the entire family of Chromel-Alumel thermocouple grade alloys—plus much helpful technical application data. Write for your copy today!

**The words "Chromel" and "Alumel" are registered trademarks of*

HOSKINS MANUFACTURING COMPANY

4445 Lawton Avenue • Detroit 8, Michigan

In Canada: Hoskins Alloys of Canada, Ltd., Toronto, Ontario

Producers of Custom-Quality Resistance, Resistor and Thermoelectric Alloys Since 1908

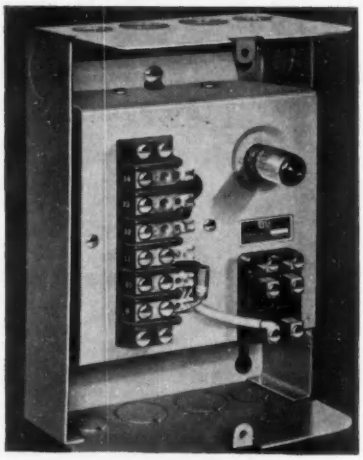
CIRCLE 162 ON READER SERVICE CARD

NEW PRODUCTS

Products Co., Hawthorne, N. J., has announced a Model SS-779-1 light weight compact **dc tachometer** priced at $32.50, that has armature inertia of only 3.5 gm-cm². . . . (332) Direct measurement of high pressure flows (50,000 psi) is now possible using the new series of **transmitting rotameters** available from **The Brooks Instrument Corp.**, Hatfield, Pa.

Circle Nos. 330, 331, or 332 on reply card

CONTROLLERS, SWITCHES & RELAYS



FOR LOW SENSITIVITIES

Designed for level control applications where the liquids have low specific resistance, this Type 50-101 electronic floatless controller is particularly suitable for food or dairy processing since it will not contaminate products. Also, shock and sparking hazards are eliminated at an electrode potential of 9 vac and an electrode current of 26 ma. Specific resistance range is 120-4,700 ohms in direct operation, 340-10,000 ohms in inverse operation.—B/W Controller Corp., Birmingham, Mich.

Circle No. 333 on reply card

BILLION OPERATION RELAY

Particularly applicable to computers and data processing equipment and in machine tool operations, this mercury wetted contact relay is designed to give over a billion operations with

A NEW ADDITION TO THE SONAC *LINE*

POSITIVE ULTRASONIC LEVEL CONTROL

The components of Sonac (sensor actual Size)

Now, two new ultrasonic sensors, especially for level control have been added to the Delavan line of SONAC sensing and switching devices.

The single sensor system is recommended for liquid level control and the double sensor system for dry level control.

Control is maintained by installing the SONAC sensor through the wall of the vat, bin or hopper. When the oscillation on the face of the sensor is dampened or impeded by the material being sensed, the signal to the control unit changes, activating a relay.

FIG. 1—LIQUID LEVEL (One Sensor)

FIG. 2—DRY LEVEL (Two Sensors)

For level control, SONAC is accurate to .005" and has a response time of 25 milliseconds. Performance of the sensor does not deteriorate with age.

The level control uses to which SONAC can be applied are virtually unlimited. It is not affected by the viscosity*, specific gravity, conductivity, or capacitance of the material being sensed. Temperature or pressure changes of the material do not alter its performance. False signals are eliminated because SONAC may be adjusted so as not to sense steam, foam, or vapors.

*Viscosity may affect response time.

Canadian Representative:

KNOWLES & FOSTER (North America) Ltd.

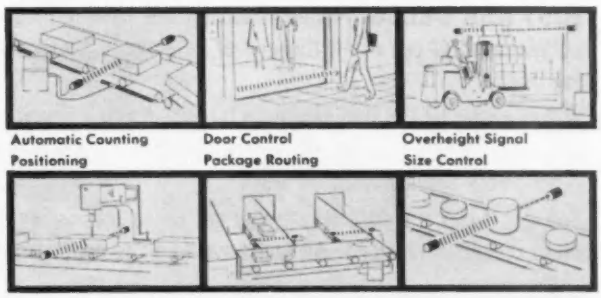
708 Terminal Bldg., Toronto 1, Ontario, Canada

A

SONAC is extremely rugged. Sensors are type 304 stainless steel. The electronic components in the sensors are hermetically sealed and will withstand pressures to 2000 psi and temperatures from −425° F. to +450° F. They are immune to shock, vibration or mechanical damage.

The control is a compact unit 5" x 5" x 5" and features transistor circuitry. Power consumption is one watt and the unit will operate in temperature ranges from 40° F. to 135° F.

Here's how SONAC can be used for sensing and switching applications other than level control.



Automatic Counting Positioning | Door Control Package Routing | Overheight Signal Size Control

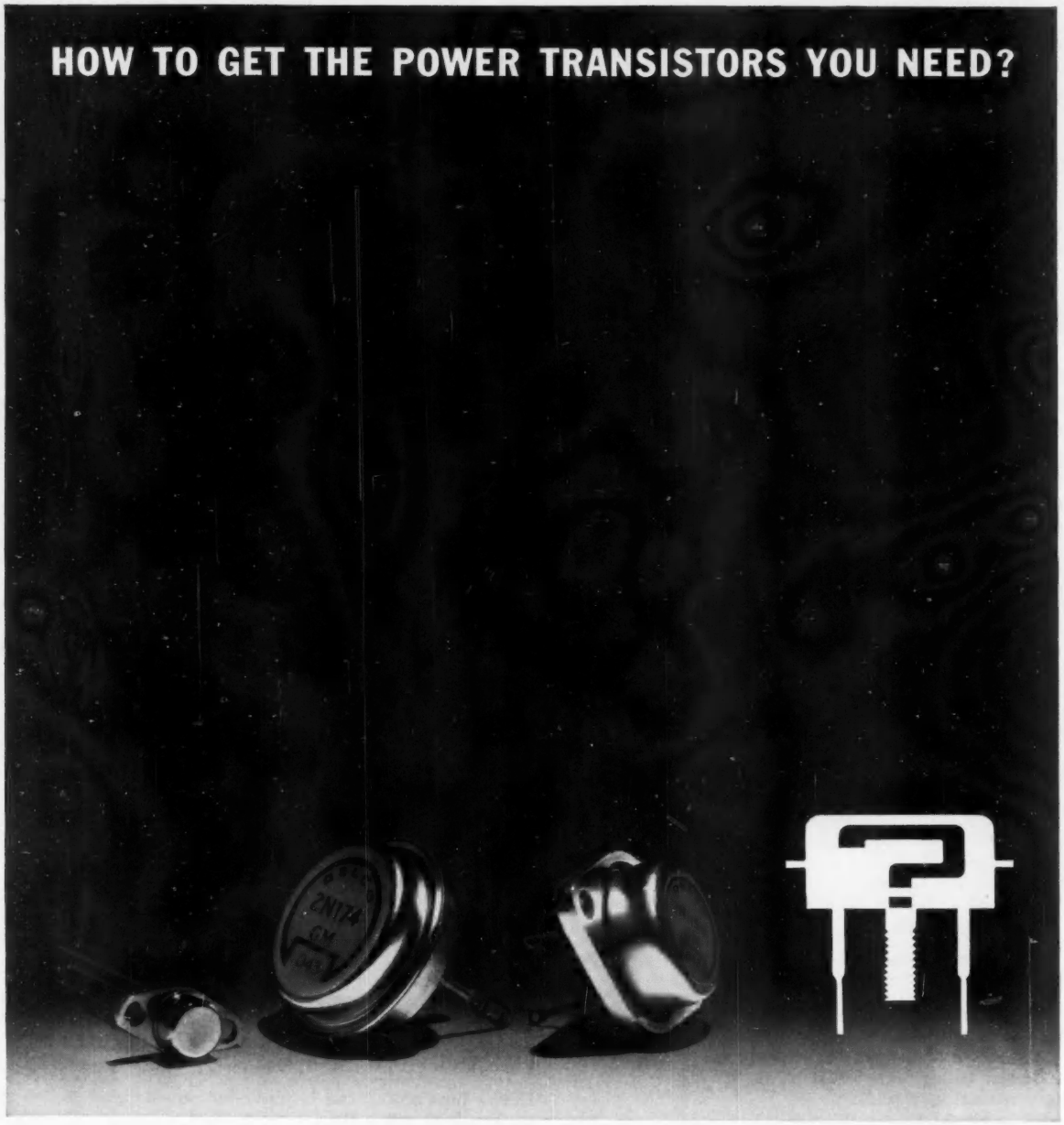
There are dozens of applications for SONAC *single and double sensor units. Let it go to work for you now, write:*

DELAVAN Manufacturing Company

WEST DES MOINES • IOWA

CIRCLE 163 ON READER SERVICE CARD

HOW TO GET THE POWER TRANSISTORS YOU NEED?



JUST ASK DELCO. For even though our catalog lists only a handful of germanium power transistors, there is only a handful out of all those ever catalogued that we don't make. And those only because nobody ever asked for them.

We've made, by the millions, both large and small power transistors. Both diamond and round base. Both industrial and military types. And each in a wide variety of parameters that have proved themselves reliable in nearly every conceivable application.

You get Delco transistors fast. You get Delco transistors in any quantity. And for all their high reliability, you get them reasonably priced. All you have to do is contact our nearest sales office—and ask for them.

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726 Santa Monica Blvd.
UPton 0-8807

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POrtsmouth 7-3500

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57 Harper Avenue
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RELIABILITY

Division of
General Motors
Kokomo, Indiana

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Ask for a complete catalog

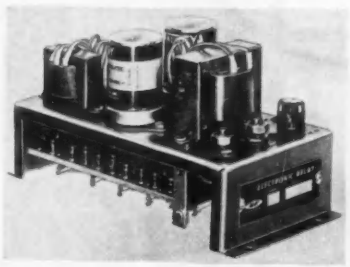
DELCO RADIO
DEPENDABILITY
RELIABILITY

CIRCLE 165 ON READER SERVICE CARD

NEW PRODUCTS

complete freedom from contact bounce. The Series V51 has a minimum operate time of 3 millisec with a coil input of approximately 2 watts. Release time is 3-3½ millisec under any coil input power. The switch capsule can be driven at up to 100 operations per sec. Loads of 250 va can be handled with 5 amp, 500 volts as maximum. Minimum operating sensitivity is 250 mw. In a steel housing with octal plug, the relay measures 1.105 in. in diam by 3.196 in.; weight is 4 oz. Price: $9.50.—Automatic Electric Co., Sub. of General Telephone & Electronics Corp., Northlake, Ill.

Circle No. 334 on reply card



NEEDS NO SUPPLY

This solid state relay does not require a separate dc power supply since a supply for 25 volts, 150 ma dc is built in. Input required is 115 volts, 60 cps. Turnon point is adjustable from 30 to 150 volts input by a sensitivity control. Hysteresis control—independent of the sensitivity control—is used to set turnoff point. This hysteresis control range is 50-100 percent of turnon voltage. Unit measures 8 x 4 x 4 in.—K-F Products, Inc., Denver, Colo.

Circle No. 335 on reply card

12-VALVE CONTROLLER

Compact new controller permits operation and timing of up to a dozen valves in sequence. Designed to be used with the manufacturer's No. 1825 electric remote control valve, the device is especially suitable for controlling water flow in industrial processes. Valves may be set to open at any time and flow from 3 to 60 min on individual cycles. Any valve cycle can be shut down without affecting others. Price: $140.—Febco, Inc., Los Angeles, Calif.

Circle No. 336 on reply card

SENSES ALL METALS

This new proximity limit switch detects any metal object without physical contact. Nonferrous metals at up to ¼ in. and ferrous metals at up to 1 in. away can be sensed. A transistorized circuit is encapsulated in the operating head for protection against coolants or other contaminants, and the sensor will even operate under water. Switch is rated at 30 vdc input, 30 vdc at 250 ma output. Maximum repetitive accuracy is to within 0.005 in.; maximum differential is 0.01 in. Operating time is 20 millisec. Price for sensor plus power supply: about $93.—General Electric Co., Schenectady, N. Y.

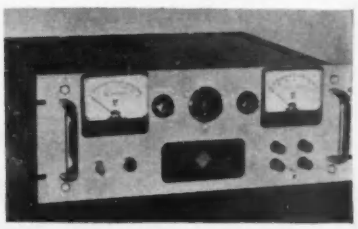
Circle No. 337 on reply card

POWER SUPPLIES

STANDBY POWER

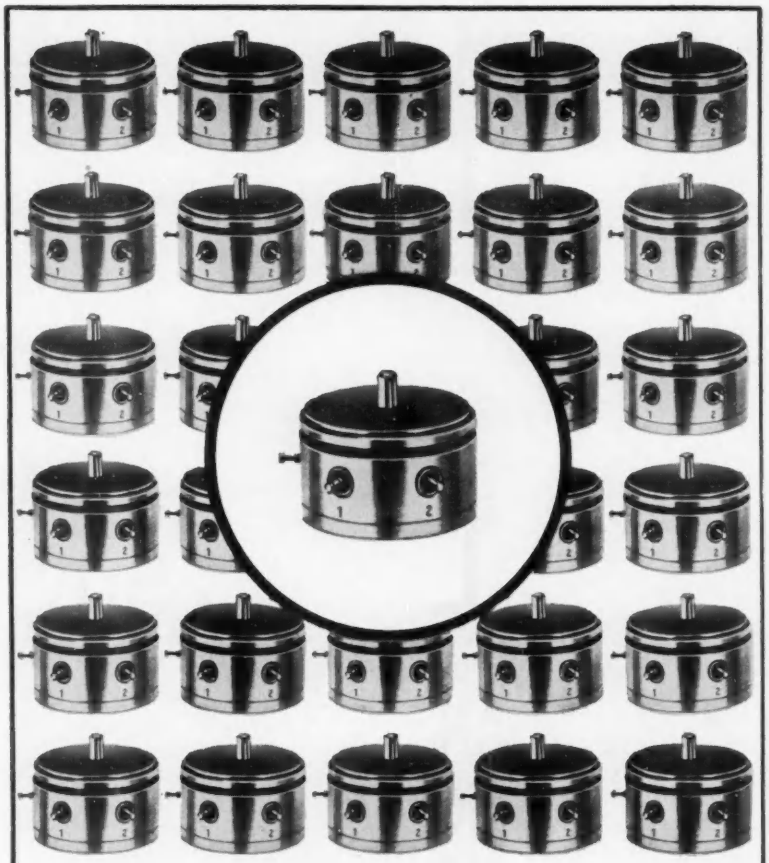
Featuring zero switchover time, this system is intended for use in applications in which power interruption of even a single cycle will destroy intelligence sequences. The Electro-Pac "A" system provides ac from a battery source, regulating the voltage to ±7 percent. Sine wave output has 3 percent maximum harmonic distortion. All solid state, the device uses transistors and silicon controlled rectifiers. Outputs from 500 va to 3 kva are available. — Electro-Seal Corp., Des Plaines, Ill.

Circle No. 338 on reply card



OVERVOLTAGE PROTECTED

A feature of this new ST Series of transistorized power supplies is built-in



NOW . . .

Metal Film Potentiometers

Here is a new addition to MECHATROL'S product line of precision rotating components . . . . . METAL FILM POTENTIOMETERS.

Using a unique new process, MECHATROL manufactures the deposited film potentiometer resistance element in a high vacuum chamber using electron bombardment techniques. This provides a thin film metallic resistance element of extremely fine granularity capable of being resolved into infinitely small changes in resistance. Resolution is better than .005%.

MECHATROL'S thin film potentiometer exhibits superior wear and rotational life under conditions of high ambient temperature and severe vibration and shock. Standard units measure 1-1/16 inches in diameter and are available for servo or panel mounted applications. Special units designed and manufactured to meet your exact specification.

FEATURES:

Resolution . . Better than .005%
Temperature . —55°C to +125°C
Vibration . . . 10 g's, 10-2000 cps.
Rotational Life . . 2,000,000 cycles @ 40 RPM

Write for full details.

SM/I SERVOMECHANISMS/INC.

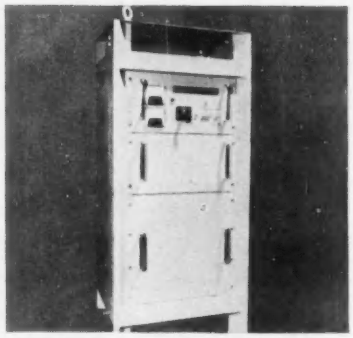
MECHATROL DIVISION

1200 Prospect Avenue, Westbury, New York

MECHATROL OF CALIFORNIA, 200 North Aviation Blvd., El Segundo, California

overvoltage protection. A total of 10 models are included in the group suitable for applications including transistor life testing, computers, and film resistor testing. Output of the supplies ranges from 0 to 100 vdc and from 0 to 35 amp. Line regulation is to within 0.01 percent, and load regulation is from 0.01 to 0.05 percent. Ripple is under 1 mv rms. Prices range from $495 to $1,595.—Mid-Eastern Electronics, Inc., Springfield, N.J.

Circle No. 339 on reply card



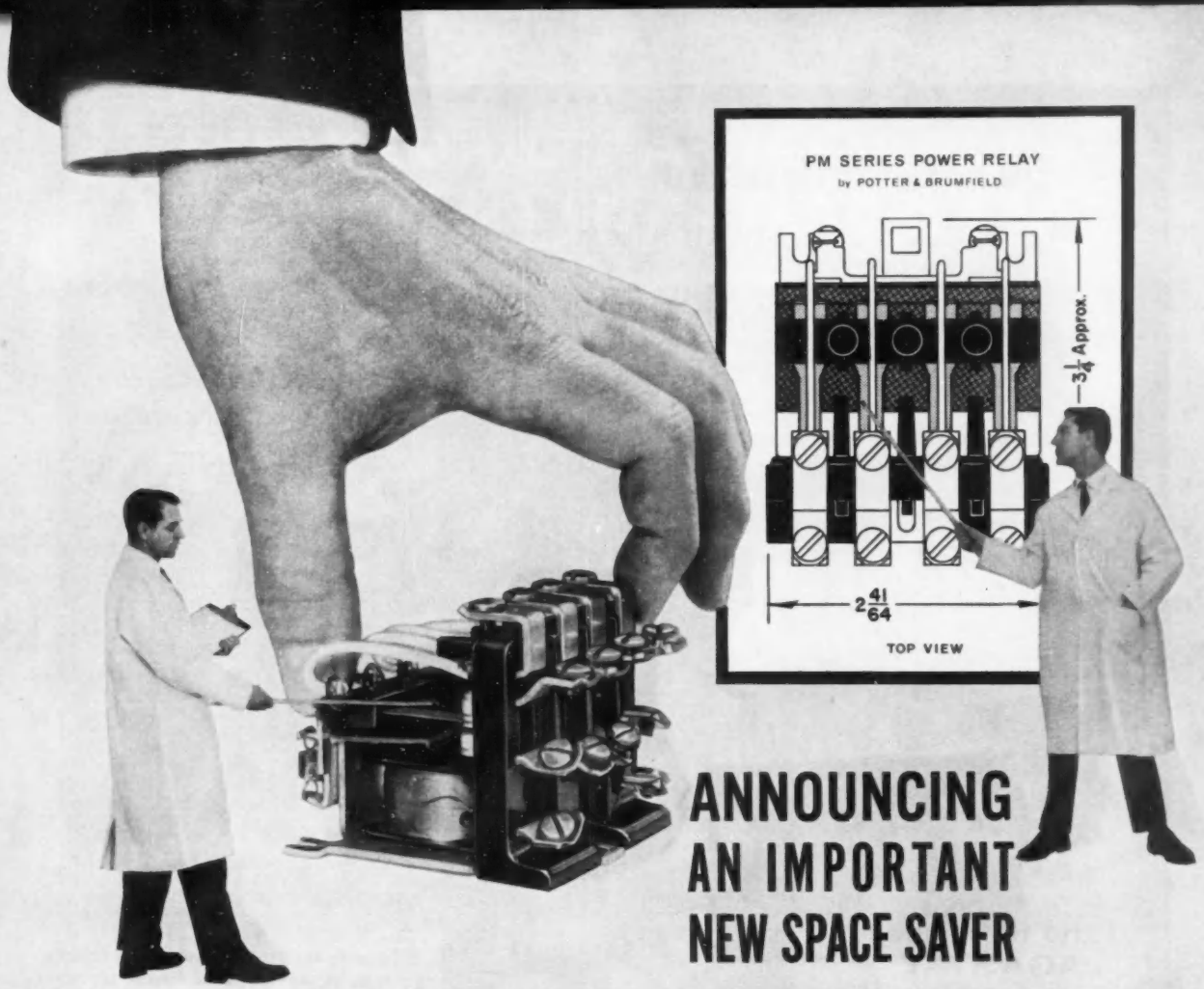
SUPPLIES COMPUTERS

Designed for applications where continuous emergency standby power is required such as for computers and in utilities, this highly regulated static inverter converts dc power from a 129-volt battery to 115 volts, 60 cps, single phase. Silicon controlled rectifier is used as the principal power regulating device. Output is 3.5 kva at 0.7 power factor and 2.0 kva at 1.0 PF. Harmonic distortion is 5 percent or less, and regulation is to within ±5 percent. Efficiency of the 450-lb unit is 80 percent at nominal input and 100 percent load. Price of 2.5-kw inverter is approximately $5,000.—General Electric Co., Schenectady, N.Y.

Circle No. 340 on reply card

REGULATED LAB SUPPLY

Rated at 0-600 vdc at 1 amp max, this lab regulated power supply fits in 8¾ in. of a panel on a standard relay rack. The Model RTS-601 features line regulation to within ±0.05 percent or ±20 mv for variations of ±10 percent. Load regulation from no load to full load is to within 0.05 percent or 50 mv. Ripple is less than 1 mv rms.



ANNOUNCING AN IMPORTANT NEW SPACE SAVER

P&B compact 4PDT power relay switches one H.P. per moveable arm

Save panel space! This new 4-pole relay is only 3/16" wider than our PR Series, America's most popular 2-pole power relay! Yet, it is engineered for reliable heavy-duty switching . . . and you can confidently expect 10 million mechanical operations.

PM Series relays are rated at 16 amperes (or 1 H.P.) at 115 volts, 50/60 cycles resistive . . . and special relays can be supplied for loads up to 25 amperes, at 220 volts, 50/60 cycles resistive. Heavy screw terminals are arranged for fast, easy hook up. An adapter plate is available for mounting PM relays in the same location used for 2-pole relays.

For full information, write today or call your nearest P&B representative.

PR Series MR Series AB Series

A whole family of power relays for a wide range of applications carry the P&B symbol of quality. Call P&B first for all your power relay requirements.

PM ENGINEERING DATA

GENERAL:

Description: Heavy-duty AC power relay.
Insulating Material: Molded phenolic.
Insulation Resistance: 100 megohms minimum.
Mechanical Life: 10 million operations minimum.
Contact Life: 100,000 operations minimum at rated load.
Breakdown Voltage: 2,000 volts rms minimum between all elements and ground.
Ambient Temperature: −55°C to +55°C.
Weight: Approximately 14 ozs.
Pull-In: 78% of nominal voltage.
Terminals: Heavy-duty screw type with No. 8-32 BH screw.

CONTACTS:

Arrangements: 4PDT or 4PST—normally open.
Material: ¼" dia. silver-cadmium-oxide.
Rating: 16 amps @ 115 volts, 50/60 cps resistive.
8 amps @ 220 volts, 50/60 cps resistive.
1 H.P. per moveable, 115 or 220 volts AC single phase.
25 amps @ 220 volts, 50/60 cps resistive available on special order.

COILS:

Voltage: 6 to 230 volts AC 50/60 cycles.
Power: 14 volt-amps average at nominal voltage.
Duty: Continuous.

P&B STANDARD RELAYS ARE AVAILABLE AT YOUR LOCAL ELECTRONICS PARTS DISTRIBUTORS

POTTER & BRUMFIELD

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AGASTATs are electrically actuated, but are *pneumatically* timed, so their accuracy and reliability are unaffected by voltage variations, and recycling is instantaneous. Adjustment is simple and stepless over l-o-n-g time ranges. With moving parts held to a minimum, the life span of a typical unit is measured in millions of cycles.

Industrial models (left) are dial-adjusted for delays of .05 sec. to 15 min. in five ranges. Needle valve models are also available, covering the full range (.15 sec. to 5 min.) in one unit. The Miniature Agastat on the right weighs as little as 15 oz. Hermetically sealed or unsealed types for MIL Spec or other demanding applications. Saves weight, saves space.

Timing accuracy and reliability are what you would expect from AGASTAT, pioneers in the development of time delay instrumentation. Single- or double-pole versions, in all standard AC and DC coil voltages. Types to provide delay on pull-in or drop-out. Want complete specs, or further information? Just write Dept. I1-35.

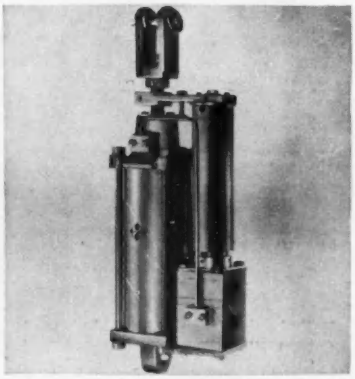
ELASTIC STOP NUT CORPORATION OF AMERICA
ELIZABETH DIVISION ▪ ELIZABETH, NEW JERSEY
IN CANADA: ESNA CANADA LTD., 12 GOWER ST., TORONTO 16

NEW PRODUCTS

Rack mounting models are priced at $854.–PRL Electronics, Inc., Rahway, N. J.

Circle No. 341 on reply card

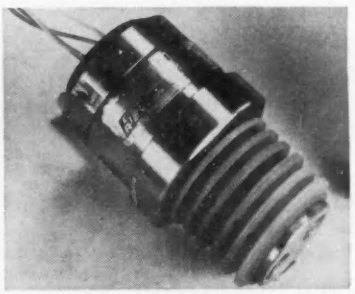
ACTUATORS & FINAL CONTROL ELEMENTS



ACCURATE POSITIONER

An accuracy to within ±1 percent is claimed for this small pneumatic power positioner that drives valves, dampers, or other loads up to 150 lb. With 100 psi of air supply and no load, the positioner takes just 1.5 sec for full stroke. Frequency response at no load and 10 percent peak to peak input signal is 1.3 cps. Front silhouette of a unit with 2½-in. bore and 5-in. stroke is 3¾ in. wide. Price: $162.50 with base.–Hagan Chemicals & Controls, Inc., Pittsburgh, Pa.

Circle No. 342 on reply card



TINY PERFORMER

The SV-128 is a miniature electro-hydraulic servovalve with the high per-

PROVED ULTRA-RELIABLE VICTOR DIGIT-MATIC PRINTERS

160,000,000 digit impressions without failure

Rugged, Trouble-Free—Digit-Matics are specially built to stand the strain of continuous operation. In a durability test, over 160 million digit impressions were made without breakdown or need of adjustment. The machine tested operated continuously, eight hours per day until 160 million digit impressions were made. During this period only normal lubrication and cleaning were performed.

Parallel or Serial Entry — Automatic and unattended, solenoid-activated Digit-Matics print out alpha-numeric data from remote equipment. High speed parallel entry models accept up to 10 digits at a time, print up to 4 lines per second. Serial entry models accept 1 digit at a time, up to 11 per line.

Two-Color Printing — Positive values in black, negative values in red. Ideal for "accept-reject" sequences, testing applications, accumulating data from two sources on one Digit-Matic, and many other uses.

Adaptable to Your Specific Needs — Line includes listers, accumulators and calculators. Versatile units can handle degrees, minutes, seconds, fractions. Other modifications: superimposed keyboard for manual use, time readings, counters, etc.

Immediate Field Service — 70 factory service branches and service representatives in over 600 cities assure uninterrupted operation. Victor offers 30-day delivery on most Digit-Matics. Mail coupon now for product data and application information.

VICTOR
ELECTRONICS DIVISION

Victor Adding Machine Co., Chicago 18, Illinois
Victor Adding Machine Co., (Canada) Ltd., Galt, Ont.

Manufacturers of Digit-Matic Printers, Scanning Printers, Electrical Keyboards, and Digit-Matic Data Punches

Victor Adding Machine Co. CE-5
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Send full information on Victor Digit-Matics.

My application is_____

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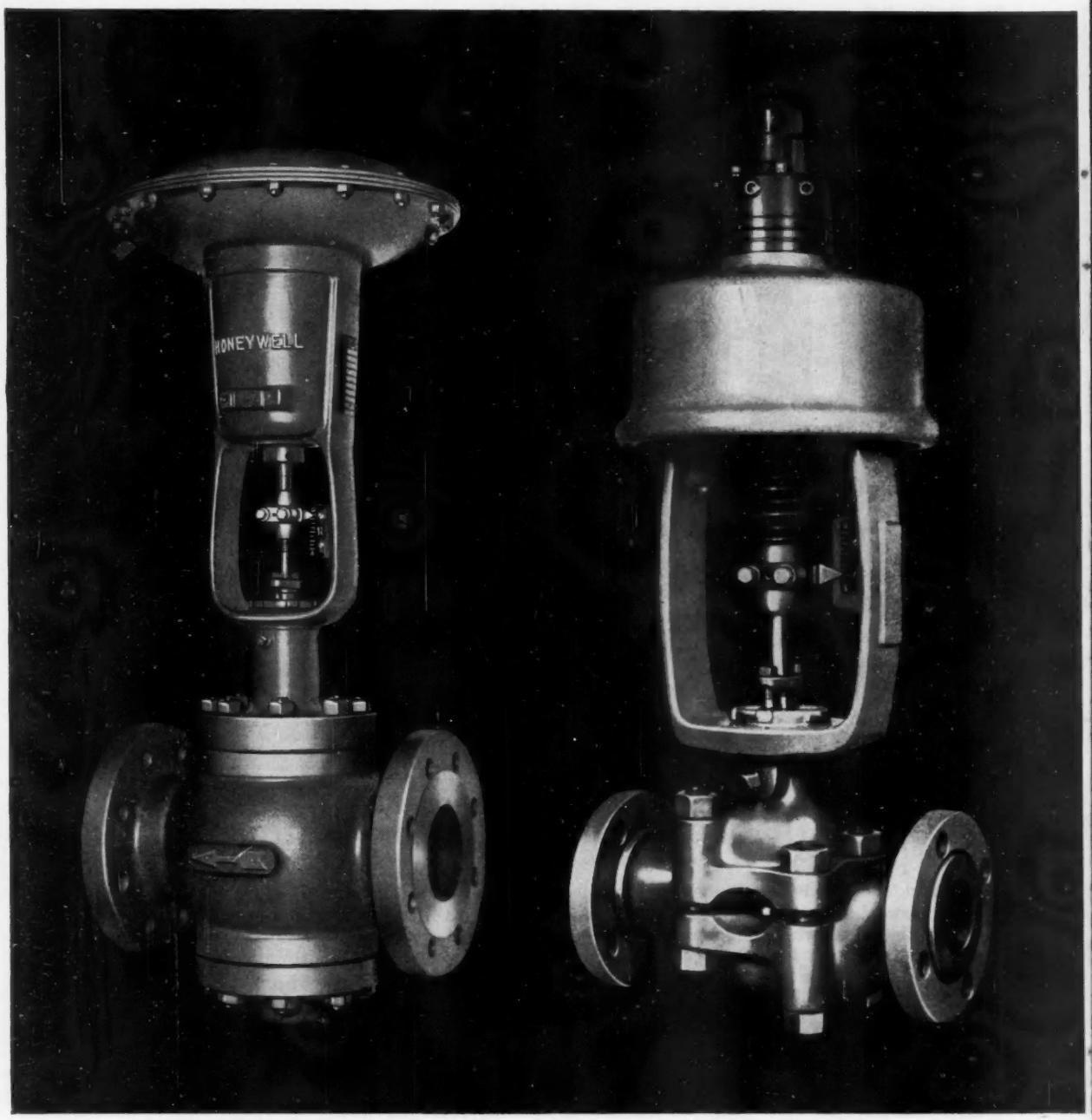
CIRCLE 169 ON READER SERVICE CARD 169

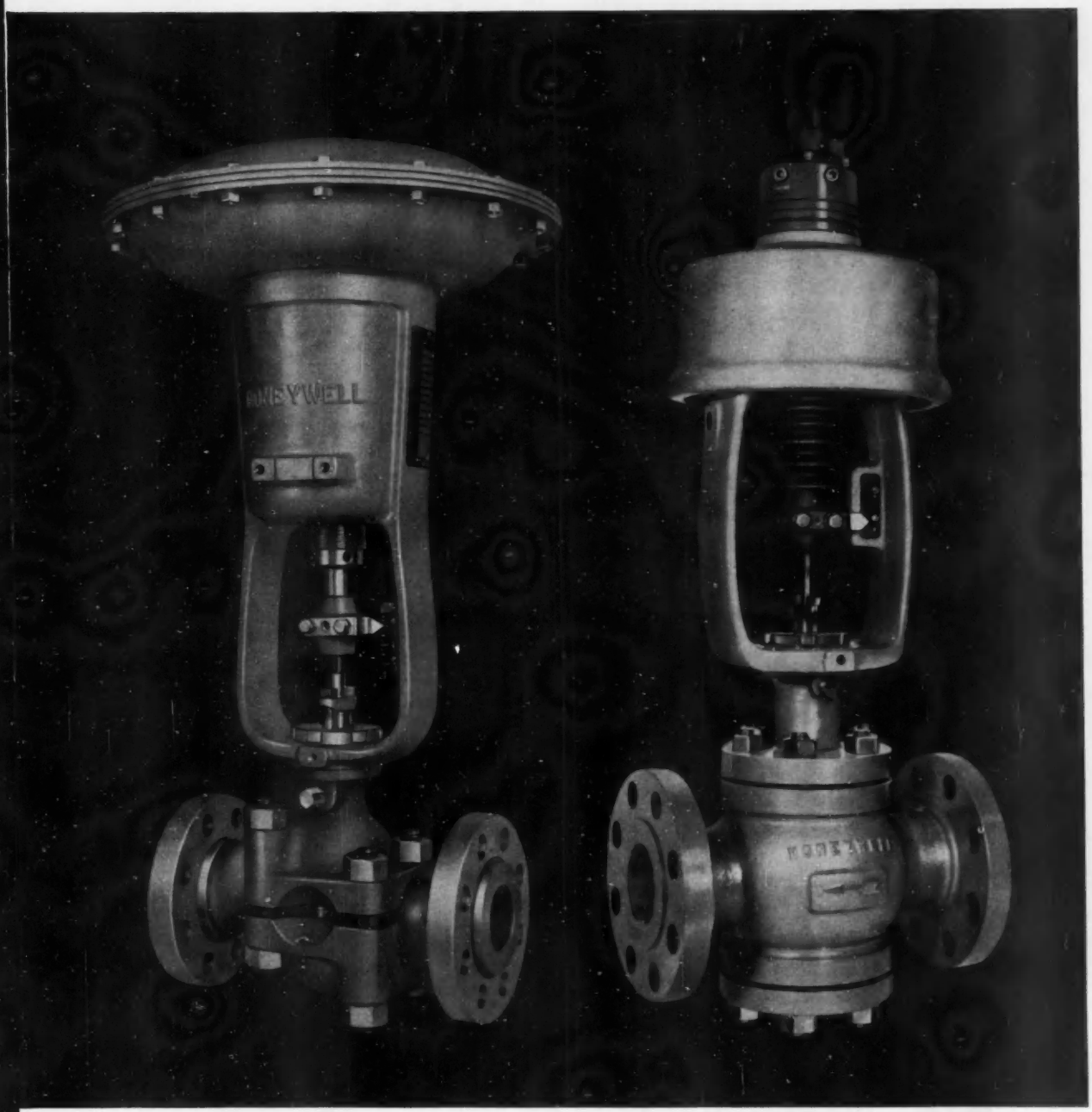


The lineup, left to right—Diaphragm actuator, globe body . . . Cylinder actuator, split body . . . Diaphragm actuator, split body . . . Cylinder actuator, globe body.

Interchangeable!

MIX THEM, MATCH THEM TO THE JOB . . . AND SAVE!

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.



Honeywell's split-body and globe-body control valves team up beautifully with Honeywell cylinder and diaphragm type actuators. Use either actuator with either valve. The beauty lies both in the economy and perfect matching to the application made possible by this interchangeability. The "mix and match" versatility of Honeywell valves and actuators lets you select the exact degree of performance you require. No need to push a valve beyond its design limits, on one hand, or to pay for more performance than you need, on the other. You get the best valve-actuator combination for a given application, at the lowest cost. The new Honeywell "Valve Size Computer" helps you make your *mix and match* selection . . . send for yours today. MINNEAPOLIS-HONEYWELL, Fort Washington, Pa.

Honeywell

First in Control

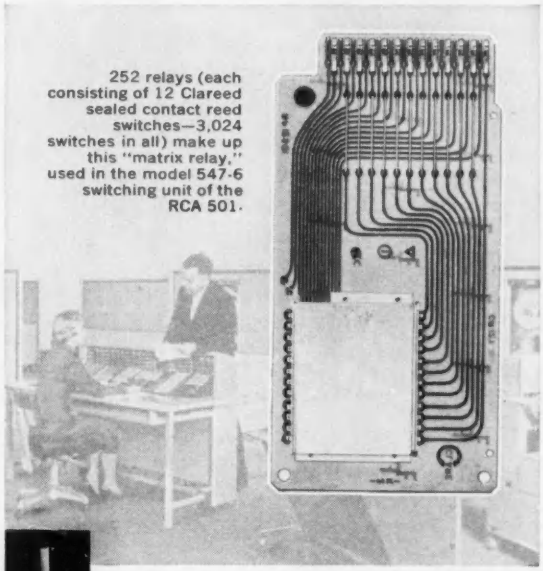
SINCE 1885

CIRCLE 171 ON READER SERVICE CARD 171

RCA uses 252 CLARE

Printed Circuit Relays in the 501 electronic data processing system

RCA's 501 incorporates many advanced features which significantly increase reliability as well as economy of space, weight and power.



252 relays (each consisting of 12 Clareed sealed contact reed switches—3,024 switches in all) make up this "matrix relay," used in the model 547-6 switching unit of the RCA 501.

CLAREED Sealed Contact Relays provide fast, sure switching

Contributing to the efficiency, speed and compact structure of the RCA 501 are 252 CLAREED sealed contact reed relays. These relays, their contacts hermetically sealed in contaminant-free inert gas, assure millions of perfect operations... hundreds of millions when operated at up to ½ rated load. Low inductance, and the low inductance change at each operation, limits the transients produced.

These relays may be mounted to meet almost any requirement. Consult your nearby CLARE sales engineer...or write: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., 840 Caledonia Road, Toronto 19, Ontario. Cable Address: CLARELAY. Ask for Bulletin CPC-10.

C. P. CLARE & CO.
Relays and Related Control Components

NEW PRODUCTS

formance features of much larger valves selling for much more. The Minivalve features an in-line force feedback system for high performance with low leakage. Only 1 1/16 x 3/4 in. and weighing only 4.5 oz, the Minivalve's unique plug-in design allows it to be introduced easily into a servosystem. Valve is simply slipped into a prepared receptacle and screw-down collar is tightened. A long life, flexible nylon seal and stainless steel fluid area assure the valve will not be affected by many fluids ranging from water to acid for periods up to 10 years. Single nozzle orifice configuration in the first stage flow circuit is twice as large as in a conventional two-nozzle servovalve. Plugging by contaminants is greatly reduced since particles greater than 200 microns can pass.—Sanders Associates, Inc., Nashua, N. H.

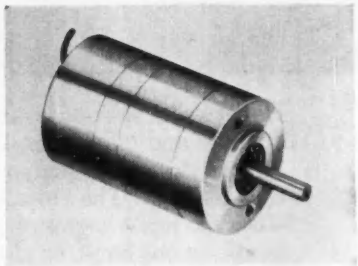
Circle No. 343 on reply card

LINEAR CHARACTERISTICS

A new high rotor impedance servomotor has been designed to have a linear torque vs speed characteristic and an unusually high torque to inertia ratio. The latter provides the 400-cps unit with fast acceleration.

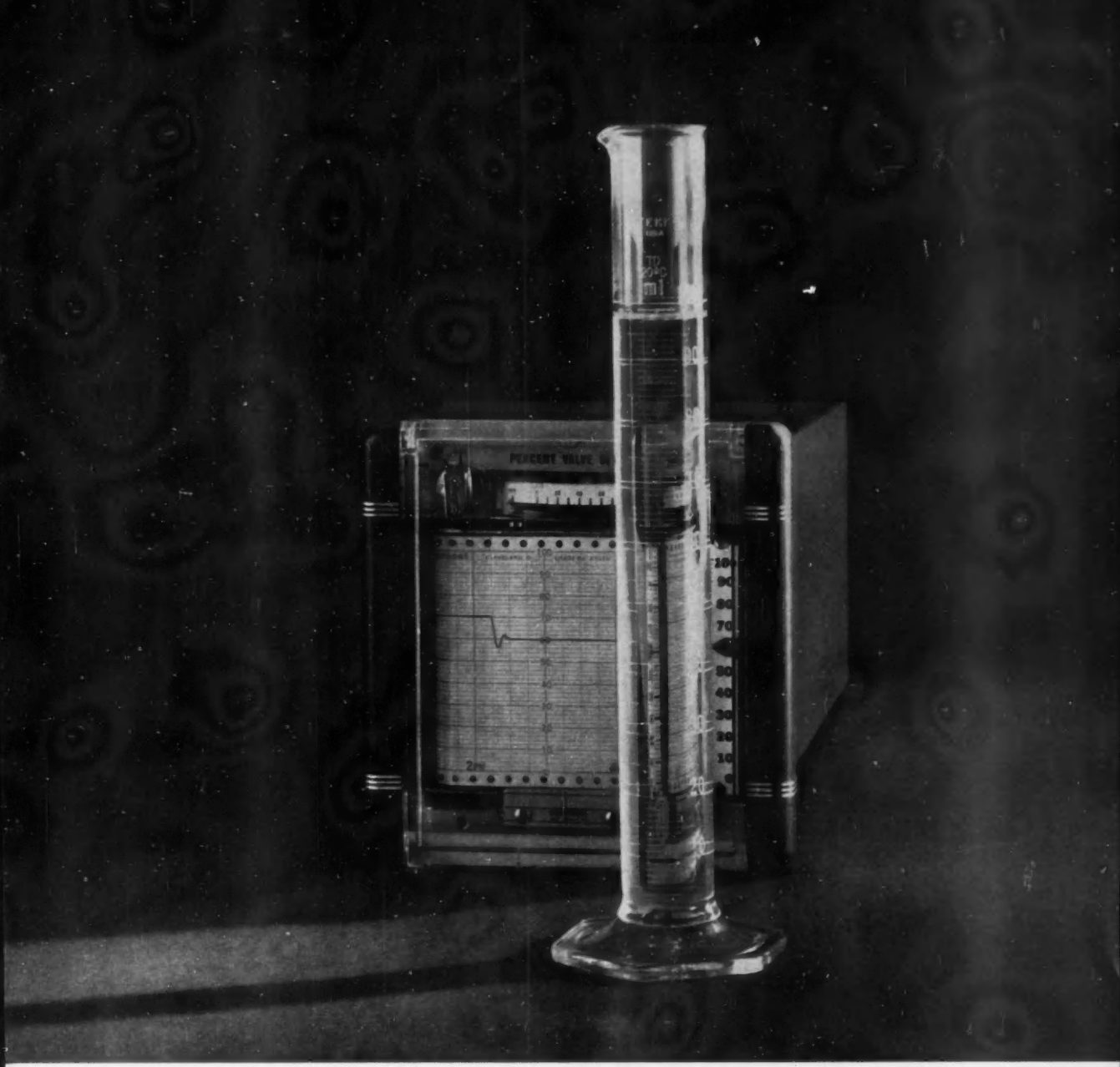
Characteristics:
Minimum no load speed: 6,500 rpm
Acceleration: 88,000 rad/sec²
Torque at stall: 1.25 oz-in.
Torque²/inertia: 110,000 oz-in./sec²
Power input: 115 volts, 8.5 watts
Dimensions: 1½ in. in diam by 1½ in.
Weight: 9 oz.
Price: $148 for single units
—Kollsman Motor Corp., Dublin, Pa.

Circle No. 344 on reply card



SMALL EFFICIENT MOTOR

This new HYLM permanent magnet dc motor is the smallest in the manufacturer's line of subfractional horsepower motors designed to MIL specifications. Only 1 in. in diam, the device boasts high efficiency (53 per-



WE GOT OUR FEET WET 4 BILLION BARRELS AGO

4,000,000,000 barrels of oil (even greater quantities of chemicals) have gushed, gurgled, surged, spurted and, in some cases, oozed in precise response to Autronic® control loop signals.

There have been remarkably few troubles reported. In the beginning, of course, there were the inevitable design bugs. But now, 20,000 loops later, the bugs have all been worked out.

As a result, when you specify Swartwout, you get instrumentation that has shown—on the job—that it can do the job. You get all the advantages of electronic controls and the assurance and security that only a decade of field operation can provide.

Swartwout people know electronic instrumentation, and they would be glad to share that knowledge with you.

Interested? Send for Bulletin A-913.

SWARTWOUT

SWARTWOUT DIVISION, CRANE CO.

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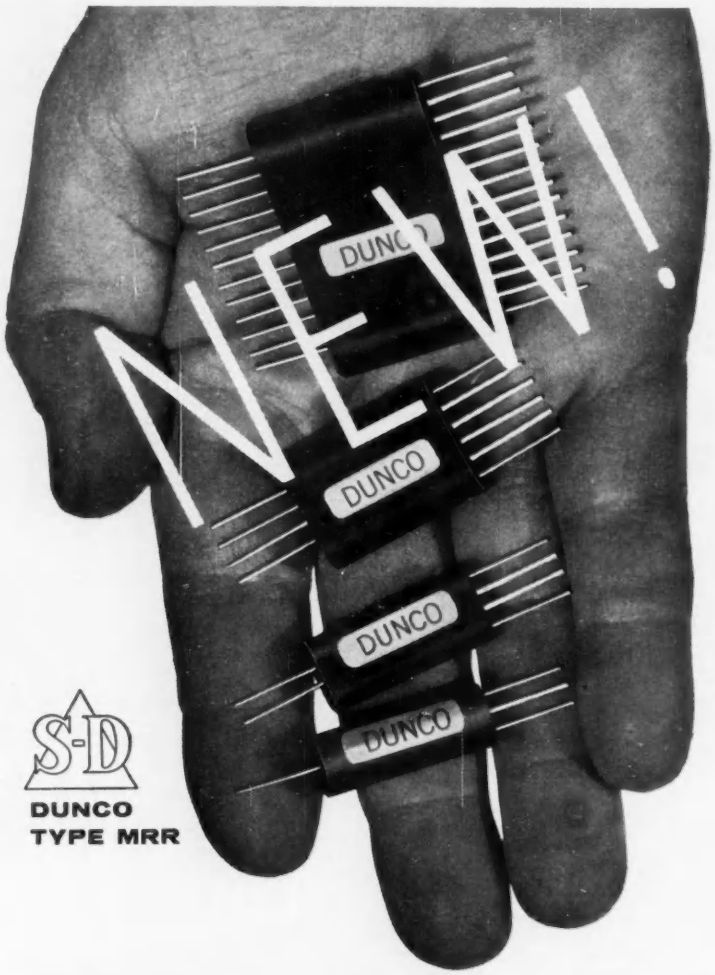
SWARTWOUT . . . World Leader in Electronic Process Control

moving fast with CRANE

CIRCLE 173 ON READER SERVICE CARD



Miniature Reed Relays

1, 2, 4 and 12-POLE ENCAPSULATED TYPES

12 poles in a sturdy unit only 2-1/8" long
(including leads) x 19/32" deep x 1-25/32" wide! . . .
1, 2 and 4-pole types similarly miniaturized . . .
designed for reliable light load switching . . .
In-line terminals for 0.1" grid center mounting . . .
Normal operate times less than 1 msec for 1-pole units . . .
2.5 msec for 12-pole . . .
Release less than 0.3 msec for all . . .
Write for Bulletin MRR-1 to:
Struthers-Dunn, Inc., Pitman, New Jersey

STRUTHERS-DUNN

World's Largest Assortment of Relay Types

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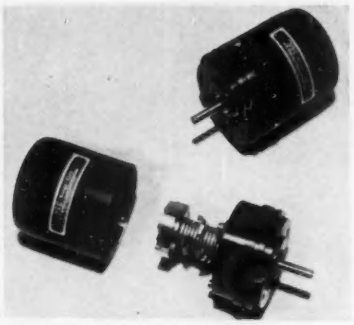
cent). Three lengths are available, and motors designed to operate on voltage of 6-115 vdc can be supplied. For a 27-volt unit at 17,000 rpm, torque is 1 oz-in.—Barber-Colman Co., Electrical Components Div., Rockford, Ill.

Circle No. 345 on reply card

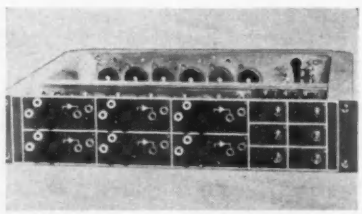
COMPONENT PARTS



BROAD RANGE LIMIT STOP

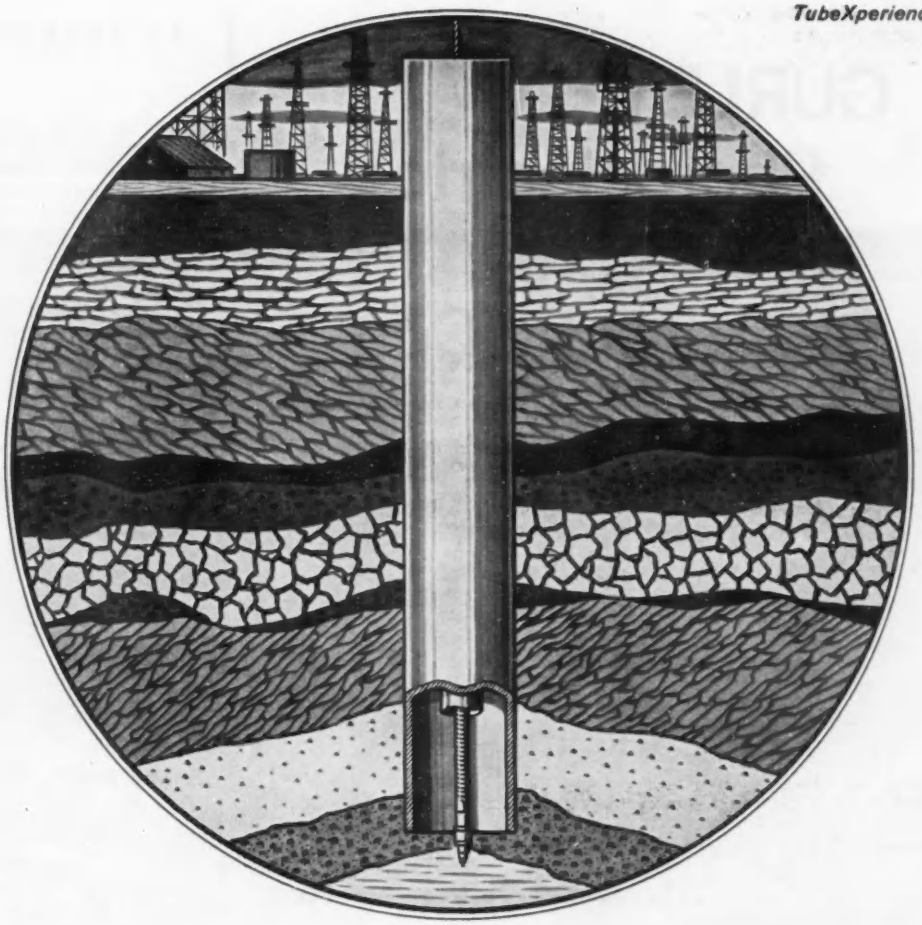
This improved limit stop assembly provides fully adjustable rotational limit control within an operational range of 30 to 4,530 deg. The self-contained unit is available in Size 18 (1¾ in. diam) with a ⅞ — in. case. Adjustment is by setting a series of washers, each governing 300 deg rotation. Preset units are also available. Price: about $56.—PIC Design Corp., E. Rockaway, N.Y.

Circle No. 346 on reply card



SIX-PACK

Newest addition to this manufacturer's line of analog computer building blocks is the C/06P/S/CO stabilized operational amplifier six-pack. Unit features a front panel fixed patch bay which accommodates six plug-in am-



Deep well pressure readings within .05% accuracy with help of Superior Ni-Span C* Bourdon Tubing

Accurate down-well pressure readings, indicating changes of only 1 to 4 psi at bottom-hole pressure of 2000 psi, are hard to get, but extremely important. They demand a pressure gage accuracy of at least 0.1% to make the vital engineering calculations based on them of any value.

To achieve this accuracy and better it, Superior was asked for help in selecting the Bourdon tube material for an improved bottom-hole measuring device. After careful study, its metallurgists recommended Ni-Span C nickel-chrome alloy for the Bourdon tubes. This material was chosen for its relative insensitivity to temperature changes, coupled with superiority in operating temperature, mechanical hysteresis, and elastic drift; also for its fatigue resistance and spring properties.

The customer followed the suggestion and now this gage, which is unique in bottom-hole pressure instruments for the reason that it utilizes a helix-wound Bourdon tube to transmit directly the effects of pressure to a recording stylus, is rated 0.1% accurate. In fact, with special care in operations and calibration, it can measure within .05% accuracy.

NI-SPAN C TUBING NOW STANDARD AT SUPERIOR

Ni-Span C redraw stock is now in inventory at Superior, available for immediate production in a range of sizes from .010 in. to ⅜ in. OD, up to .125 in. wall max., and from ⅜ in. to 1⅛ in. OD in wall thicknesses up to .035 in. max. Shaped tubing can be produced to customers' prints. Perhaps you have an application that can benefit from its unusual properties. Write for Data Memorandum No. 19. Superior Tube Company, 2026 Germantown Ave., Norristown, Pa.

*Registered trademark of International Nickel Co.

Superior Tube

The big name in small tubing

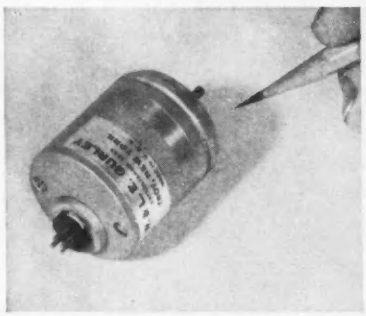
NORRISTOWN, PA.

All analyses .010 in. to ⅜ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

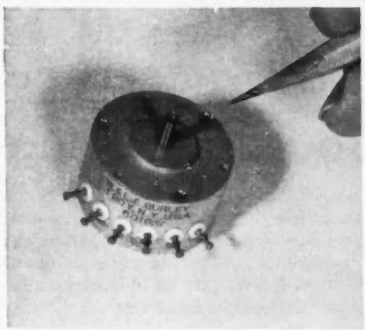
GURLEY Photoelectric PULSE GENERATORS Add...Subtract...Count

Gurley photoelectric pulse generators are shaft-driven, delivering electrical pulses at terminals. Pulse frequency is directly proportional to shaft speed; and pulse amplitude is independent of shaft speed. **Used basically as rate generators or as angle-measuring devices.** All models available with direction-sensing photo cells.



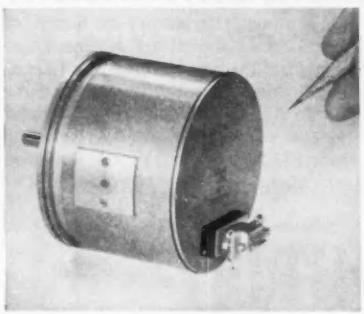
Model 8601

Synchro Mount ..... 1.437" dia.
Length ..... 1.875"
Up to 1024 apertures
Inertia ..... 2.8 Gm-Cm²
Torque ..... less than 0.1 in.-oz.



Model 8602

Housing Diameter ..... 1.375"
Length ..... .844"
Up to 1024 apertures
Inertia ..... 2.8 Gm-Cm²
Torque ..... less than 0.1 in.-oz.



Model 8603

Synchro Mount ..... 3.4" dia.
Length ..... 2.6"
Up to 5000 apertures
Inertia ..... 340 Gm-Cm²
Torque ..... less than 0.1 in.-oz.
Built-in amplifiers available.

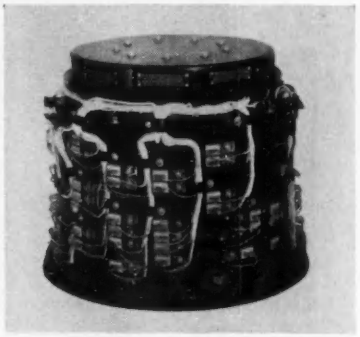
Write for information on one or all.

W. & L. E. GURLEY, TROY, N. Y.
537 Fulton Street

NEW PRODUCTS

plifiers to provide six channels of high gain drift stabilized analog computation. Unit is programmed by plugging in standard precision resistors and capacitors with interconnecting standard patch cables. Input is +300 vdc, −300 vdc, and 115 vac, 60 cps. Price: $195.–Embree Electronics Corp., W. Hartford, Conn.

Circle No. 347 on reply card



NONAMBIGUOUS DATA STORE

Contact heads read and write data in this magnetic drum that features large capacity, nonambiguous digital storage. They are being offered after operating in the manufacturer's own military computers. The heads are in direct contact with the drum until it reaches operating speed; then surface air movement raises the heads a few millionths of an inch. This is said to give characteristics comparable to noncontact heads, with better efficiency. Minimum write current is 300 mv; read signals to 1 volt are possible. Reduced crosstalk allows one-word recirculating tracks with 18-bit words at 160 bits per in. packing density.–Computer Systems Laboratory, Litton Systems, Inc., Woodland Hills, Calif.

Circle No. 348 on reply card

BIDIRECTIONAL REGISTER

Single flip-flop mounted on a printed circuit card of this bidirectional shift register element controls information to either the right or the left. Either series or parallel readin and readout is possible. As a shift right, shift left 10-bit unit, it may be used as a reversible preset decade counter. In the shift right, nondestructive readout mode, the device may be used to present information to high speed printers or card punchers. Maximum oper-

MORE VALUE / LESS COST

CC108R

Versatility of the Conoflow LB valve makes it suitable for any control service—easy or tough. Write for literature today or contact your local Conoflow representative (in all principal cities) for prices.

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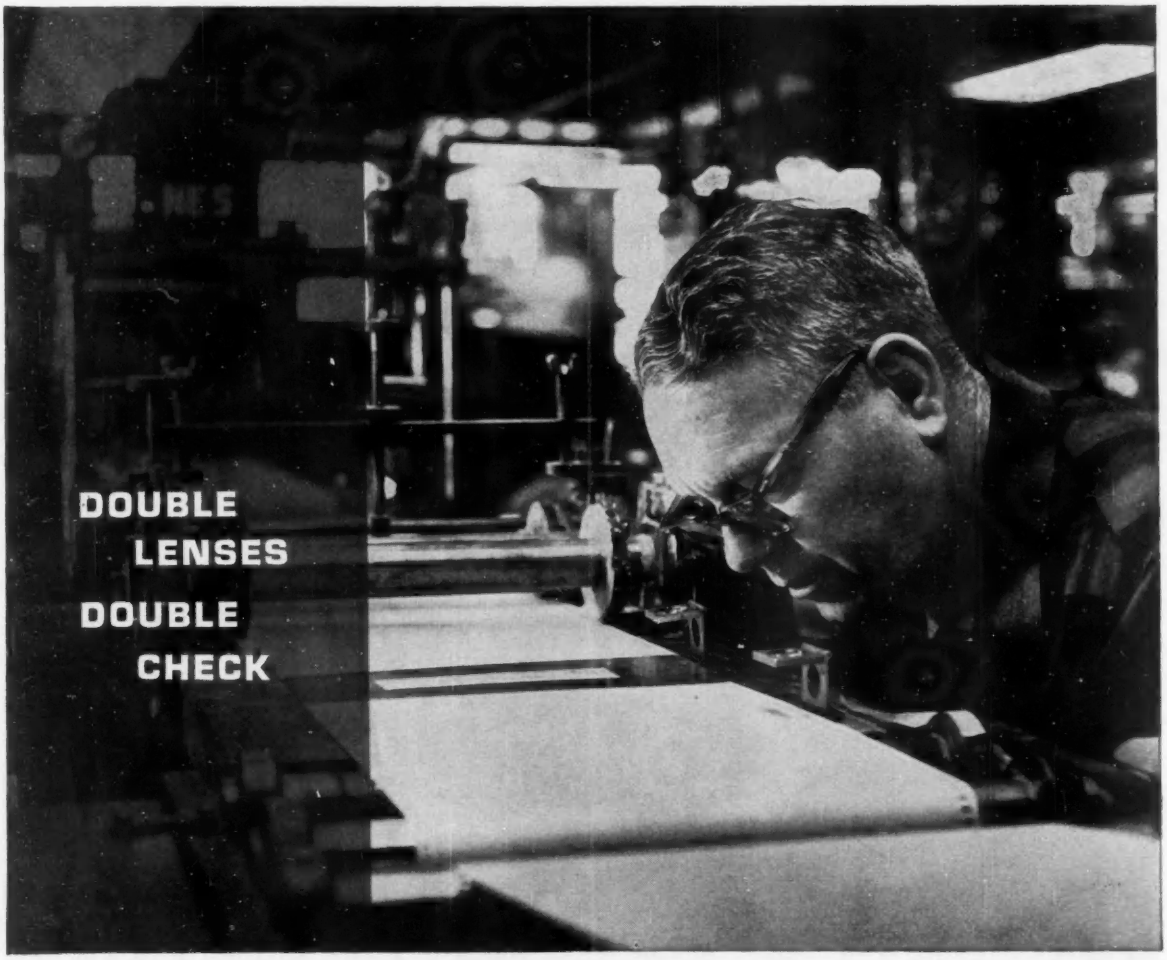
CIRCLE 177 ON READER SERVICE CARD 177



. . . for the precise calibration that means RECORDING CHART DEPENDABILITY

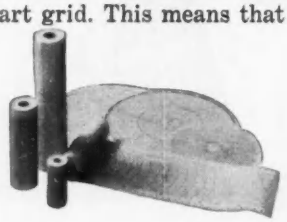
Charlie Robinson, our pressroom supervisor, is making a careful chart calibration check in the picture above. He does this often.

To make this test Charlie uses two engraver's glasses, a special templet . . . and the 50 years of chart printing experience that stands behind every GC Recording Chart.

What this test involves is making sure that the center line of the circular punches on a GC Strip Recording Chart is always the same distance — the *correct* distance — from the zero line of the chart grid. This means that a 25 psi recording at the end of a process, for example, will have the same value as a 25 psi recording at the start.

Take rigid inspection standards like these — and add repeated paper and ink tests, continuous humidity control in production and storage areas, and speed of printing and delivery. You'll see why more than 5,000 chart users rely regularly on GC dependability.

GC stocks more than 15,000 different chart types. We design and print charts for special purposes. Why not send now for the GC Stock List and for specific sample charts?



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This portfolio, yours for the asking, tells eight ways you'll benefit by standardizing on GC direct-writing charts. It holds a sheaf of samples to give you the "feel" of the ultra-smooth, specially milled paper on which GC Charts are printed. On the back is a handy guide for ordering the GC direct-writing charts that will meet your needs.

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Firm_____
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NEW PRODUCTS

ational frequency is 100 kcps. Price: $175. – Magnetics Research Co., White Plains, N. Y.

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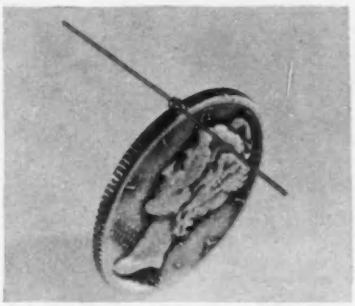


SMALLEST HERMETIC DIODES

Two microminiature glass diodes—first in a new series of such devices, to be tradenamed Micro/G diodes—are smaller than the head of a pin. This makes them the smallest hermetic diodes ever offered, according to their manufacturer. A reduction of volume of 50 to 1 is achieved for these units, the TI-2 and TI-6, over conventional diodes with similar characteristics. Package diameter is 0.040 in., length is 0.060 in., and round leads are used. These diodes are designed for computer applications such as logic circuits and high speed switching. Reverse recovery times are 10 and 100 millimicrosec, respectively.–Texas Instruments, Inc., Dallas, Tex.

Circle No. 350 on reply card

PLUS . . .

(351) A militarized solid state, high gain, direct coupled **operational amplifier** module for general purpose closed-loop use is available now from **Dynamic System Electronics Corp.**, Scottsdale, Ariz. . . . (352) **Digital Development Corp.**, La Jolla, Calif., has added a 12-in., 50-track, 300-cps model to its line of MIL-spec **magnetic memory drums.**

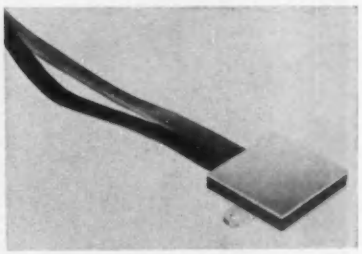
Circle Nos. 351 or 352 on reply card

ACCESSORIES

COLUMN PROGRAMMER

The Model 22 linear temperature programmer extends the capabilities of gas chromatographs by accurate, linear, reproducible programming of column temperature. A total of 39 different heating rates as well as precise isothermal operation are offered. Direct column heating is also a feature. Price: $1,200. – Perkin-Elmer Corp., Norwalk, Conn.

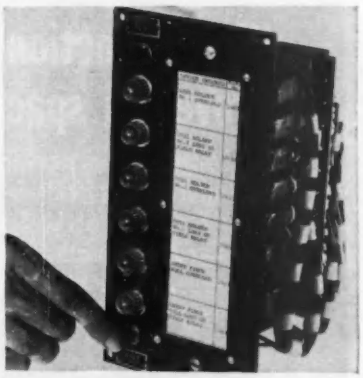
Circle No. 353 on reply card



THERMOELECTRIC COOLER

Now available from stock are these thermoelectric devices made up of several semiconductor junctions designed for spot cooling of electronic circuits. These modules, measuring 1½ x 1½ x ½ in., can handle more than 20 watts or maintain a temperature differential of 80 deg C between hot and cold plates. Several modules can be connected in series or parallel for greater cooling capacity. A complete TA-20M Thermo-Module ready for use with ⅛ in. thick aluminum plates at top and bottom is priced at $91.06. –Ohio Semiconductors, Div. of Tecumseh Products Co., Columbus, Ohio.

Circle No. 354 on reply card



FAULT FINDER

Low voltage incandescent lamps indicate faults and malfunctions in electrical control equipment when this newly announced static fault finder is used. Static magnetic switching and memory circuitry is employed. One to six devices can be monitored. When a contact set opens in any device, an indicator lights to show the

6 FLIGHTS—6 SUCCESSES...
A PERFECT RECORD FOR KIDDE!
Kidde reaction control systems:
Proven in space...available now!
Kidde designed and is supplying complete hydrogen peroxide reaction control systems for the second and third stages of NASA Scout and Air Force Blue Scout. Systems and components available in 30 days—not in 3 months or 3 years!
Save development funds by choosing a Kidde system of known reliability, proven in space, and available now!
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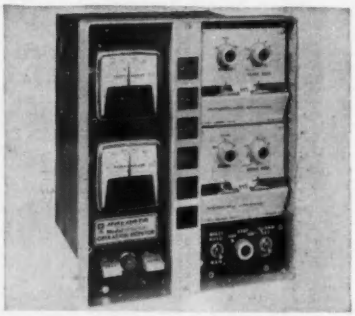
NEW PRODUCTS

location of the fault. A reset button extinguishes all lights, but if a fault has not been corrected, its light will reappear. – Clark Controller Co., Cleveland, Ohio.

Circle No. 355 on reply card



TWO-CHANNEL MONITORS

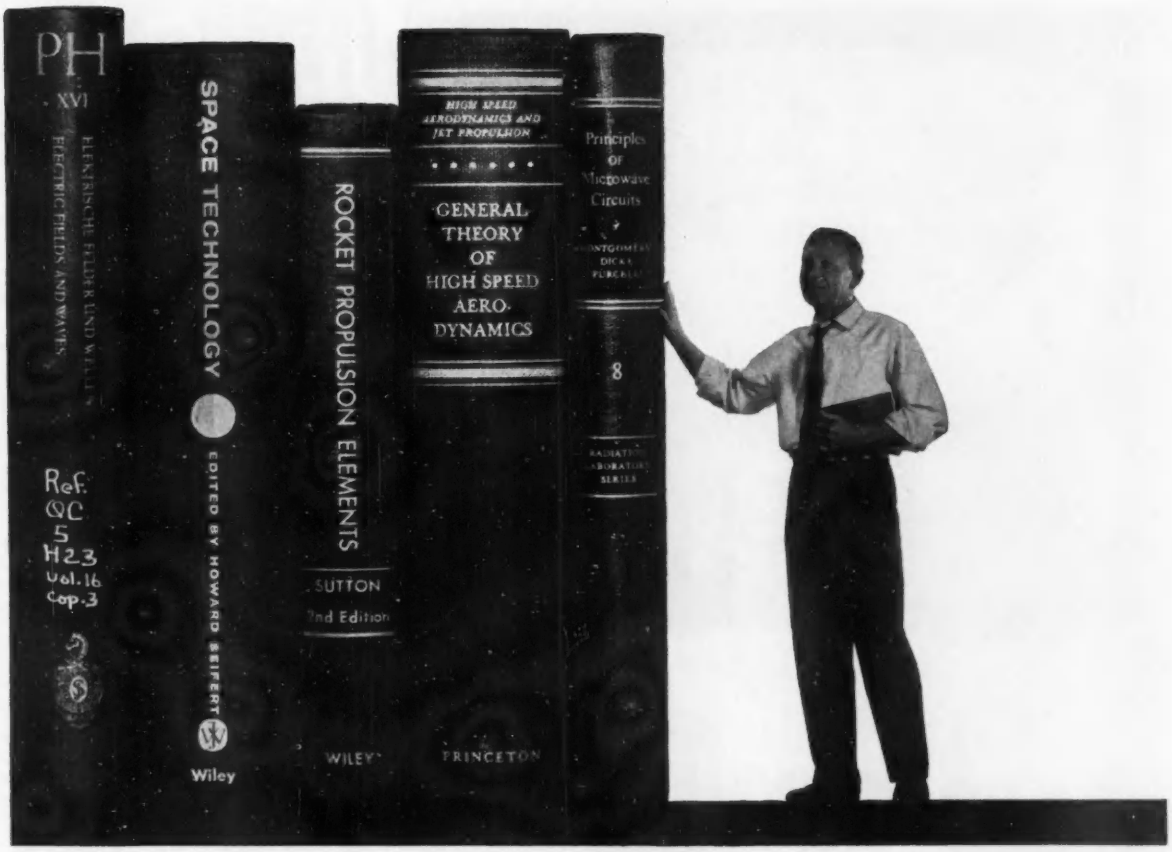
These Series 18 operation monitors translate amplitude and frequency of signals obtained by pickup devices attached to machines into normal and off-normal indications. Normal, alert, and alarm signals are given to panel lamps and external relay contacts. Two limit levels on two separate data channels can be accommodated or two characteristics of a signal from one pickup can be monitored. Signal levels of frequencies are presented on panel meters calibrated in displacement, velocity, acceleration, strain, pressure, and optical reflectivity. – RayData Corp., Columbus, Ohio.

Circle No. 356 on reply card

AIDS THREE WAYS

Designed to operate with the manufacturer's IR-4 and IR-7 infrared spectrophotometers, this tracking accuracy control performs three functions: automatic slit control, automatic speed suppression, and automatic period suppression. The first feature increases the slit width under strong absorption conditions where instrument response lags. Automatic speed suppression reduces scanning speed when narrow, intense bands are encountered and the wavelength drive is moving too fast for recorder response. The period suppression feature produces a quiet curve in flat regions and an accurate short period response in strong absorption bands. Price: $1,425.–Scientific and Process Instruments Div., Beckman Instruments, Inc., Fullerton, Calif.

Circle No. 357 on reply card

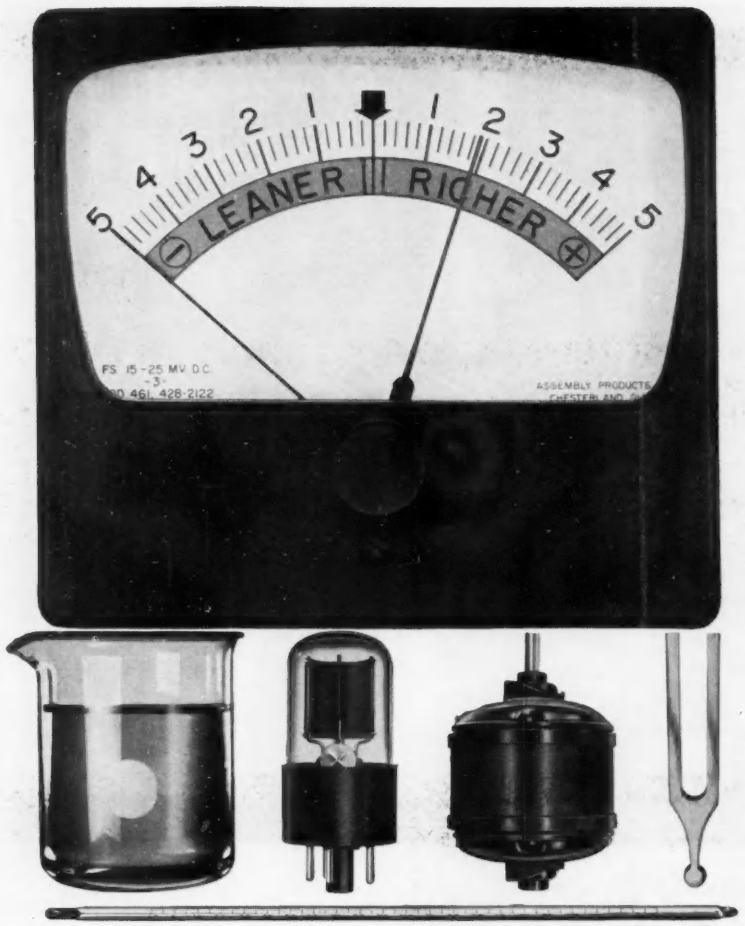


space systems planning and engineering in a unique role

The scientists and engineers of Aerospace Corporation are in the forefront of advanced planning and general systems engineering. Their unique role: critical civilian link uniting government and the scientific-industrial team developing space systems and advanced ballistic missiles. In providing broad scientific and technical leadership to every element of this team, they are engaged in activities spanning the spectrum from formulating new weapons systems concepts to technical supervision of the over-all industry team performing research, development, and test of missile/space systems. Specific activities include investigation of techniques for improving the state-of-the-art in propulsion, structures, guidance, communications and other engineering skills related to missile/space missions; feasibility studies of new weapons systems concepts and preliminary design of promising systems; formulation of development programs; conduct of critical experiments; technical supervision of the development and test program. Men with these backgrounds are invited to write to Mr. George Herndon, Aerospace Corporation, Room 124, P. O. Box 95081, Los Angeles 45, California.

Organized in the public interest and dedicated to providing objective leadership in the advancement and application of space science and technology for the United States Government.

AEROSPACE CORPORATION



WITH A. P. I. METER-RELAYS YOU CAN MONITOR AND CONTROL JUST ABOUT ANYTHING!

Handy gadget, the A.P.I. meter-relay. You can use it to indicate, monitor, and control practically any electrically transduceable variable. Things like moisture content, pH, motor load, radiation level, temperature, speed, light, sound. And, because it's so highly sensitive (0-5 microamps or millivolts is the minimum range), you can pipe-in thermocouple, strain gauge and other low-level signals directly, without amplification.

It's a highly reliable device, too. You can reasonably expect to get at least 10,000,000 perfect make-break operations. You'll probably get twice that many. We have.

You can spec A.P.I. meter-relays in any range you want, from the minimums mentioned up to 0-50 amps or 0-500 volts, AC or DC. We can calibrate scales in any units you require. Control setpoints can be either single (high or low) or double (both high and low). Catalog 4J will give you much useful and interesting information about meter-relays. It will also give you detailed, explicit specs and prices. Yours for the asking, of course.

api **ASSEMBLY PRODUCTS INC.**
CHESTERLAND 77, OHIO

SA 2396

WHAT'S NEW

(Continued from page 44)

today, the advance of microminiaturization, may have widespread effects on industry's acceptance of electronics. These ultrasmall circuits have evolved with built-in reliability, and since they will someday be produced in low individual-cost quantities, they can lead the way to the kind of servicing that industry—aware of its limited supply of electronics technicians—is looking for: plug-in modules for small circuit functions (rather than whole circuit cards), with throwaway units possible.

Banks to Run All Business? Waterbury Bank Shows How

A prediction was made in Chicago recently that banks would take over the accounting tasks of industrial firms and become business' financial hub. Speaking as director of electronics research at the Armour Research Foundation, Virgil Disney pointed out that small banks, unable to justify a computer's cost for their own needs, could invest in them if they pooled their use. Two days later, 800 miles away, the Waterbury National Bank announced in Connecticut that it had leased a Bendix computer with just such a service center in mind.

The bank believes it is the first to establish a commercial data processing service. Main reason for the move was to justify a computer, since banking volume alone would not.

Rem Rand Adds Curb Service Computer

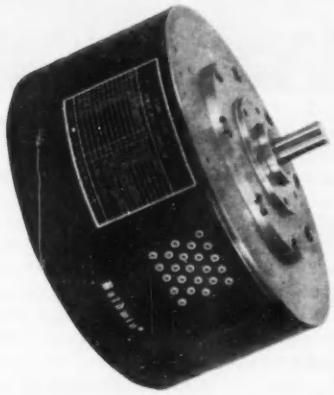
Computers on the hoof is the latest service offered by computer makers to make it easy for customers to start using their machines. Carrying the service center idea several giant steps further, Univac Div. of Sperry Rand Corp. has mounted a Solid State 90 system in a 34 x 7 ft mobile van and has started on a 25,000-mile nationwide tour. First stop—for about a month—is in Charlotte, N.C.

Univac has set several tasks for its magnetic tape system. First, the mobile computer will allow Univac customers to start work on the magnetic tape computer while their own machine is being checked out. In between these chores, the caravan machine is to be used for staging management simulation games. As another promotional device, Univac will park the van along the route and open it to the public. General use as a mobile service center is not planned.

Baldwin®

NEW PHOTOELECTRIC

ANALOG to DIGITAL CONVERTERS



SHAFT POSITION ENCODERS

SERIES 1000 SPECIFICATIONS

Diameter: 9⅞ Inches
Depth: 4½ inches
Weight: 36 pounds

Available with solid shaft or hollow shaft.

Accuracy:

MODEL	BITS:	SECS. of ARC:
1020	18	5
1010	17	10
1000	16	20

★

WRITE FOR DESCRIPTIVE LITERATURE

AR&T ELECTRONICS, Inc.

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A wholly-owned subsidiary of the

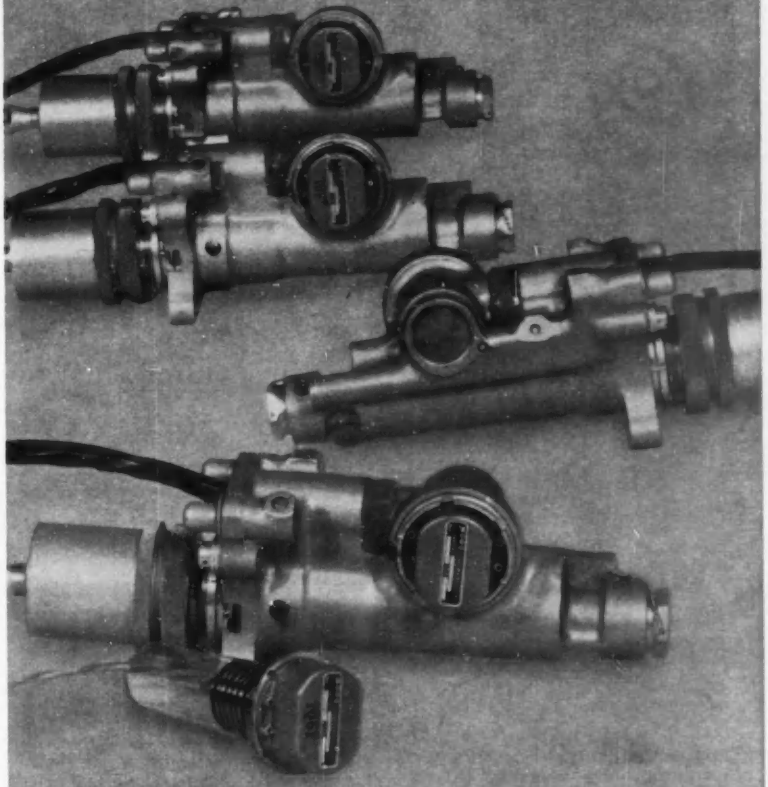
Baldwin®

PIANO COMPANY

CIRCLE 227 ON READER SERVICE CARD

RELIABILITY

THROUGH CREATIVITY AT VOUGHT ELECTRONICS



CHALLENGE: Provide the most reliable actuator ever built. Purpose: Guide the *Minuteman* ICBM.

RESPONSE: Vought Electronics—working with four valve producers*—repackaged the standard electro-hydraulic valve to achieve maximum reliability. The number of external seals was reduced. Seal configuration was made more reliable. Temperature shock sensitivity was lowered. And the finished valve—of all-steel construction—weighed less and had fewer parts than standard servo valves. This is just one of the many ways Vought Electronics has improved actuator reliability.

*Moog Servocontrols, Inc., Raymond Atchley, Inc.
Weston Hydraulics, Ltd., Hydraulic Research and Mfg. Co.

FOR A CREATIVE APPROACH TO YOUR CONTROL RELIABILITY PROBLEMS, CALL OR WRITE VOUGHT ELECTRONICS' NEW PLANT AT THIS ADDRESS:

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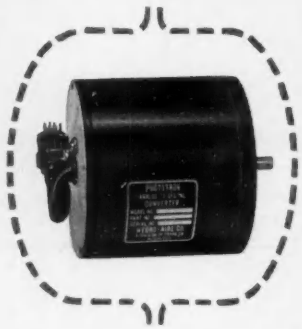
CIRCLE 183 ON READER SERVICE CARD

PHOTOTRON



FIRST IN NEW LINE OF ANALOG TO DIGITAL CONVERSION PRODUCTS FROM HYDRO-AIRE

This highly versatile basic transducer offers incremental conversion of shaft angle to digital measurement. Available in seven models, its maximum permissible speeds range from 15,000 rpm at 128 counts per revolution to 1,250 rpm at 2,048 counts, with sample rates ranging to 45,000 counts per second.

Applications for the Hydro-Aire Phototron include analog to digital shaft converters, precision analog servo with digital readout, data reduction equipment, tachometers, and precision measurement and control.

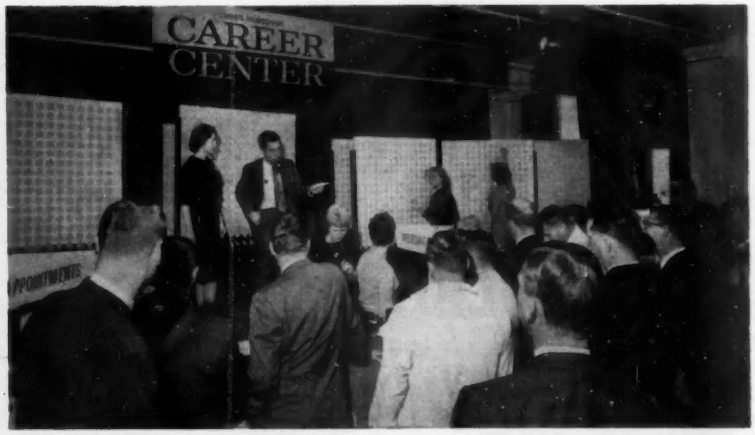
Detailed specifications are available on request. Related products soon to be available from Hydro-Aire, a member of the Crane Co. Systems and Controls Group, will include associated power supplies and binary and digital counters.

HYDRO-AIRE

3000 WINONA AVE., BURBANK, CALIF.

DIVISION OF CRANE CO.

Solid-state devices include time delay devices, voltage regulators, power supplies, inverters.



Job hunting engineers registered at the IRE Show Career Center watch a call board for their code numbers, showing that an employer wants to interview them.

Streamlined Methods Hike Recruiting at Trade Shows

Large scale, efficient recruiting methods at shows like the IRE are encouraging engineer turnover. Some companies like it, but others don't. Show managements worry: will companies send engineers to shows where they are likely to succumb to temptation?

NEW YORK—"Engineer recruiting at trade shows has come a long way," said a veteran personnel man watching some of the efficient methods of hiring at the IRE show in March. Despite the show management's official discouragement, talent hunting was publicized by bold as brass advertising and was intensive at career centers and on job bulletin boards. The improved recruiting apparently had the desired effect in hiring, but the turnover raised another question: will recruiting hurt trade show attendance?

An engineer visiting New York for the IRE show was hit between the eyes with "help wanted" before he was barely in the city. Giant billboard signs, sometimes stacked two deep for impact, invited him to a missile manufacturer's hotel recruiting suite. If he picked up a copy of the Sunday *New York Times*, he could read 15 pages of IRE show employment advertising and hundreds of inches of special classified advertising.

In a hotel across the street from the Coliseum, 53 employers cooperated in a huge career center. And even at the IRE Convention's headquarters, the Waldorf Astoria, an employment agency took over a wing to operate on behalf of a number of companies.

• **Resumés in hand**—The job market was not only a buyer's one, though. Engineers looking for new positions crowded a bulletin board set up by the reluctant show management in the Coliseum. And 2,385 job hunters packed the career center in its four days of operation.

Probably the biggest single recruiting venture, the Career Center was operated by a young New York outfit, Careers, Inc. The company was set up in 1949 by William Douglass, along with two fellow Yale University undergraduates, as the outgrowth of a job supplement published with Yale University's daily paper. It has been involved in the cooperative recruiting business ever since.

Douglass' company, also operating under the name of Career Publications, has maintained a National Manpower Register since 1958. The company relays resumés from prospects who have read of job opportunities in Careers' publications (one for experienced scientists; another for college students) to the companies who advertise in the booklets. By sending in one standardized resumé, a job hunter's qualifications are circulated to the several score companies participating. All this costs the engineer nothing; the companies pay $2,650 for their full page ads including the confidential resumé service for one year.

The service works roughly the same at a trade show. The first Career Center was run at last year's IRE show. Since then Douglass has been at WESCON, EJCC, the annual AIEE and American Institute of Physics meetings, and at an aerospace conclave in Washington, D. C., perfect-

ing his approach. Here's how it worked at IRE this year.

• **Job supermarket**—Douglass sold his service to 53 employers, including big companies (Minneapolis-Honeywell), little companies (Trak Electronics of Wilton, Conn.), government agencies (NASA, U. S. Navy, National Security Agency), and even a PhD-oriented company like the Rand Corp.

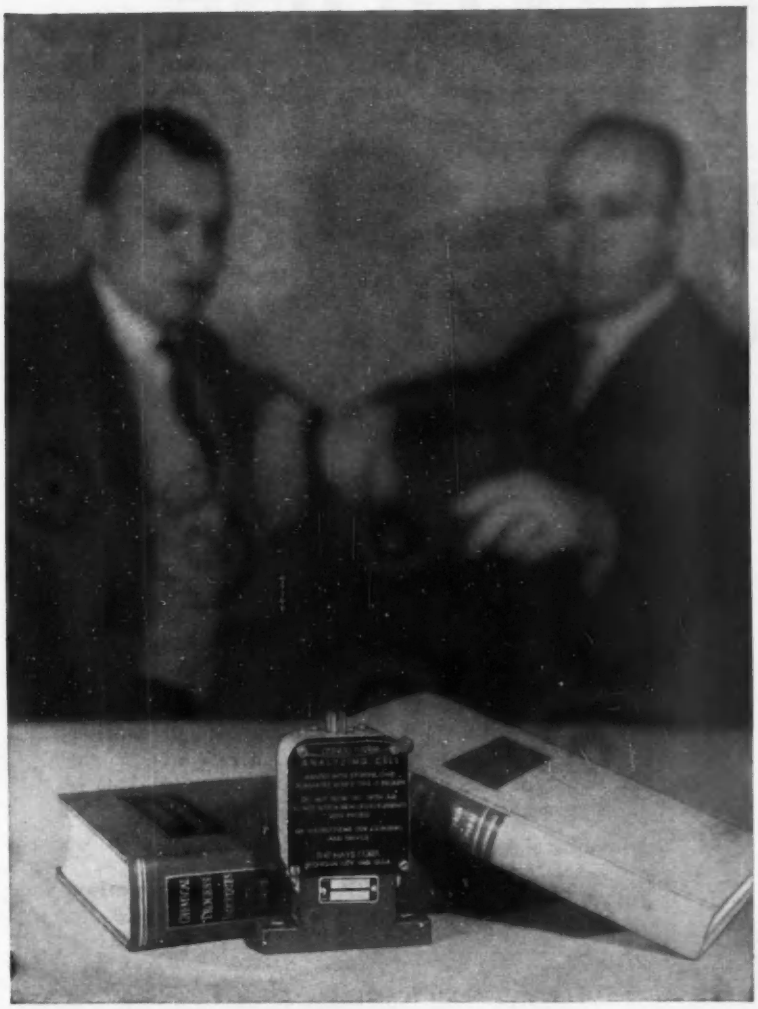
For a payment of about $1,800, each company was entitled to use interview rooms in the Henry Hudson Hotel, sleeping quarters there for its interviewers, the benefits of Douglass' large scale advertising campaign, and, most important, the resumé clearinghouse service.

A job hunter entering the Career Center first filled out a standard resumé form, listing such fundamental information as his education, type of work desired, salary requirements, geographical preference, etc. Each employer received a copy of every registrant's resumé, on which the applicant was identified only by a code number until he chose to reveal his name and present employer.

After reviewing the qualifications of the unnamed applicant and finding them worth further investigation, the employer requested an interview and the applicant's number was posted on a call board. The engineer seeking a new job could stay at the center and wait for his number to be posted—reading brochures distributed for the companies by Careers or even watching movies or slide shows set up by the employers—or return to look for this notice or call in for information. The center then arranged an interview if the applicant desired one.

That's the end of Careers' part. It collects no fee for successful placement and has no interest in the success or failure of an applicant. Careers' only other function is to send copies of the resumés of all show registrants to its publications' advertisers.

• **Small firm's chance**—How successful is this new approach? Based on interviews with IRE center participants, the clearinghouse seems to be a most satisfactory arrangement for both job hunter and employer. For a little company, Trak Electronics, for example, the center provides almost the only means of contacting large numbers of prospective employees. Trak had never interviewed at shows before, fearing it could not compete with the splashy advertising of larger companies. Also there was doubt that engineers reading such ads would even answer, since they may have never heard of Trak. At the center, Trak could request interviews, and the applicant was more likely to respond once asked. Trak recruiter Ray Frederick was looking for seven



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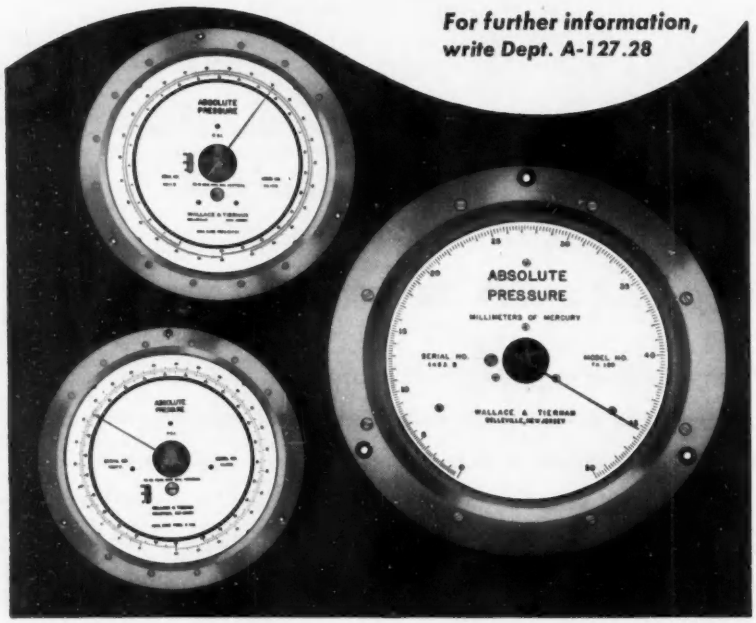

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or eight engineers with specific skills. Enthusiastic about Careers' arrangements, Frederick had requested over 200 interviews after two and half days in New York, had actually interviewed 23 men. He planned to extend employment offers to several of these.

One division of a large company which previously had interviewed on its own at shows found that its previous advertising expenses had exceeded Douglass' one-shot fee.

John Adams, assistant to the vice-president of the Rand Corp., told CtE that although he was looking for PhD-holding scientists, he had already requested 40 interviews and had spoken to over 20 men. He would follow up about a half dozen who seemed worth an offer. At last year's IRE Career Center, Rand made contacts that led to four PhD's being hired.

• **Keep them at home**—And that's what has show managements worried. How long will a small company on the West Coast, for instance, continue to pay the expenses of its young engineers for a visit to the IRE show, when they may spend a lot of time investigating job opportunities? Companies may restrict their show delegates to top people; and this could cut show attendance drastically.

Show managements and technical societies, who have tried bans on show recruiting before, are looking at the problem with renewed interest. A New York advertising agency, which specializes in recruiting, recently wrote letters to 13 engineering society secretaries, requesting that they prohibit all recruiting at their meetings. While the agency (Deutsch & Shea, Inc.) probably has its own reasons for stopping the rise of show recruiting—which now means mostly cooperative effort—still, its appeal may start society action.

Many companies (particularly defense contractors) have been accused of "stockpiling" engineers in anticipation of big contracts. This practice, in turn, often leads to the job stagnation that prompts engineers to change jobs for advancement. The combination of easy recruiting and desire for job mobility may well cloud the growth of big national trade shows.

—Stephen S. Livers

UK Instrument Sales Up

England increased its export sales of scientific and industrial instruments and apparatus in the third quarter of 1960 by 33 percent over that period in 1959. In figures released through the U.S. Dept. of Commerce, British

export sales in this field were shown to be up 20 percent from the first half of 1960. Greatest gain was in exports of industrial process measuring and control instruments. These totaled $8 million, representing 25 percent of the total production of these goods.

Total volume of all scientific and industrial instrument deliveries was 13 percent greater than in the last quarter of 1959.

Vought, Ling-Temco Reach Merger Terms, End Strife

DALLAS—

Directors of Chance Vought Corp. and Ling-Temco Electronics, Inc. have approved plans to merge the two companies which have been squabbling in the stock marketplace for the past several months. The two companies' stockholders will vote on the plan, from which Ling-Temco would be the surviving firm, in June.

L-T's president, James J. Ling, has sought to acquire Vought either by merger or stock control. Prior to the merger agreement, Ling and his associates had bought up over 455,000 of Vought's 1.19 million shares. Vought had been resisting the attempts and had filed suits against Ling claiming violation of antitrust laws.

News of Other Companies In the Control Field

Hewlett-Packard Co. of Palo Alto, Calif., and **Sanborn Co.**, Waltham, Mass., have agreed on a merger plan in which Sanborn remains a separate corporation under H-W ownership.

Giannini Controls Corp., Duarte, Calif., has acquired Cramer Controls Corp. Announcement comes two months after the Centerbrook, Conn., firm called off its merger talks with Infrared Industries, Inc.

Aerospace Control Co. is the name of a new firm organized in Santa Monica, Calif., to develop special instruments and controls for space vehicles. President and technical director is Alfred Landau.

Systems Engineering Laboratories, Inc., has been formed in Ft. Lauderdale, Fla., by several former employees of Radiation, Inc. SEL will concentrate on data handling systems.

Information Products Corp. is an electronics firm organized in Cambridge, Mass., to develop low cost information processing devices for commercial and industrial uses. Top officers of the company were formerly with Laboratory for Electronics, Inc.

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...ACCURATE METERING WITH SMOOTH CONTROL

Wallace & Tiernan's newest plunger pump delivers 3.2 gph vs 1200 psi to 50 gph vs 100 psi, repeatable within ± 1%. Easy adjustment over 10:1 range with the pump running.

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A second liquid end doubles capacity or gives simultaneous feeding of two liquids. Stroke length for each end individually adjusted.

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Chart drive response is virtually instantaneous. You can go from a dead stop to full 500 mm/sec. in less than 1/10 of a second... there's no need for adapters or gear shifting... no loss of record and no slack while chart speed stabilizes.

1000 ft. chart roll lets you do high chart speed recording at length with fewer interruptions for reloading. Accurate, easy-to-read "Remaining Footage" indicator prevents accidental loss of record due to unexpected chart shortage.

This unequalled chart speed change ratio of 5000:1 is just one more example of the overall superiority of the remarkable AO Tracemaster...the world's newest and finest 8-channel direct writing recorder.

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IMPORTANT MOVES BY KEY PEOPLE

Leifer Chief Engineer For Ampex Instrumentation

After 14 years with Sylvania Electric Products, Meyer Leifer has joined Ampex Instrumentation Products Co., a subsidiary of Ampex Corp., as chief engineer. The Redwood City, Calif., company produces magnetic tape recorders.

Leifer's last position with Sylvania was as general manager of Microwave Device Operations. He is a Fellow of the Institute of Radio Engineers.

Smith New General Manager for Potter & Brumfield

Newly announced executive vice-president and general manager of Potter & Brumfield, Div. of American Machine & Foundry Co. is Zeke R. Smith. He replaces H. L. Huntsinger who resigned his post with the Princeton, Ind., division to open a manufacturer's representative agency.

Smith will be responsible for all P&B operations, including other plants in Kentucky and Canada. He joined the company in 1953 as a sales engineer in Chicago and later moved to the Princeton Engineering Dept. In 1957 he moved up to vice-president and after two years became technical director with responsibility for all engineering. Last October he became vice-president in charge of marketing and technology.

Smith joined P&B from the Bendix Corp. He was also with Vendo, Inc. and Airborne Instrument Laboratory.

Shepherd Leaves Farrington; Scanner Setup Reorganized

David H. Shepherd, who built Intelligent Machines Research Corp. of Alexandria, Va., around his ideas in optical reading, has resigned as executive vice-president of the firm and as vice-president of Farrington Manufacturing Co., now IMR's parent company. Shepherd announced that he was leaving because of disagreement over Farrington management policies. CtE has learned that expenditures for research and development were involved.

Shepherd had been the engineering brains behind Farrington's optical reading devices, including its recently announced business page reader (CtE, April '61, p. 176). In addition, he headed IMR's fight against competitor's magnetic reading machines, working on such a reader for his own company.

In a sweeping reorganization that involved the shift of all optical scanner production to Alexandria from the firm's headquarters in Needham Heights, Mass., Farrington has hired Arthur L. Ross as senior vice-president to coordinate all data processing activities. He was president of Square D Co. of Canada Ltd.

Farrington Electronics, Inc. will now be based in Alexandria and will concentrate solely on scanning devices.

New top engineer in Alexandria is Harvey L. Cook, Jr., co-inventor of the scanner. Sales vice-president is now Theodore W. Helweg; Milton J. Grossman is in charge of administration.

Farrington expects it will have 65 scanner installations made by the end of this year. By June 1, 42 will have been delivered, with 40 on order.

Other Important Moves

W. F. Girouard is now director of industrial engineering at Librascope Div., General Precision, Inc., Glendale, Calif. He will direct the study of new manufacturing techniques and processes. He's been a consultant to Librascope in this field for two years.

Warren C. Hume has been named vice-president and general manager of the Data Processing Div. of IBM Corp., White Plains, N. Y. Hume had been IBM's midwestern regional vice-president. He has been with the company since 1939, when he started as a sales representative.

J. Penn Rutherfoord, who was general manager of the Raytheon Co.'s Commercial Apparatus and Systems Div., has joined International Resistance Co. in Philadelphia as executive vice-president. He was with GE for 21 years before coming to Raytheon.

H. Richard Lloyd has been made manager of automation and systems control sales for the Electric Utility Sales Operation of General Electric Co. Lloyd has been with GE since his graduation as an electrical engineer

in 1940. He started as a test engineer. His most recent post was as manager of utility sales in Butte, Mont.

Gilbert B. Richards, Jr., has become president of the OPW-Jordan Div. of the Dover Corp. in Cincinnati, Ohio. Richards, who is just 33, joined OPW-Jordan in 1955.

Dr. Peter I. Pollack has become director of the electronic chemicals research department of Merck Sharp & Dohme Research Laboratories, a division of Merck & Co., Inc. Dr. Pollack had a big part in developing the Rahway, N. J., firm's production of ultrapure silicon.

Dr. John A. F. Gerrard is the new director of electronics engineering for the Bendix-Pacific Div. of The Bendix Corp., No. Hollywood, Calif. Dr. Gerrard was formerly with Texas Instruments, Inc.

James B. Rudden has joined Ramo-Wooldridge, Div. of Thompson Ramo Wooldridge, Inc. to be resident engineer for R-W's Automobile Traffic Control Section in Chicago. The group is working on a project to study expressway traffic and install a pilot predictive computer control system.

Dr. Nathan Marcuvitz, director of the Microwave Research Institute at the Polytechnic Institute of Brooklyn, has been named vice-president for research at the New York school. He will direct research projects carried on by the institute that total $3.5 million in annual expenditures.

Edwin J. Jackson is now manager of aircraft instrument engineering at General Electric Co.'s Instrument Dept. in W. Lynn, Mass. Jackson has been with GE since 1940, starting on the company's rotating test program. His last post was as manager of advance equipment engineering in the Light Military Electronics Dept. in Schenectady, N. Y.

William R. Clark, manager of the Product Engineering Div., and Raymond C. Machler, director of research and development, both of Leeds and Northrup Co., Philadelphia, were among those recently honored as Fellows by the American Institute of Electrical Engineers.

Obituary

Sennet W. Gilfillan, 71; cofounder of Gilfillan Bros., Inc. and developer of the Ground Control Approach (GCA) system; at his home in Los Angeles, March 12, after a long illness.

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For a true demonstration of the readability of Rockwell-Republic V-5 gauges, cut out the actual-size photo at the right. Mount it on any wall or panel board. Step back and see how easily the scale can be read, even from 10 or 12 feet away!

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Compact V-5 gauges are equipped with electric receivers or full sized diaphragms, bellows, and helixes for maximum accuracy and sensitivity. Yet these Rockwell-Republic gauges require one-fourth the panel space needed for standard gauges.

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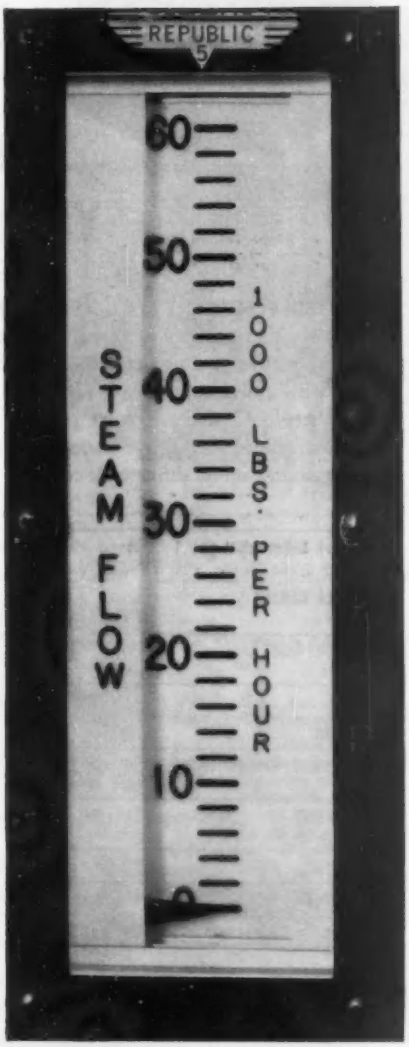
There's a V-5 gauge for almost every process measurement. Mail the coupon today for the 12-page bulletin on these easy-to-read gauges, and for available literature on other Rockwell-Republic instruments, controls, and valves. RF-22



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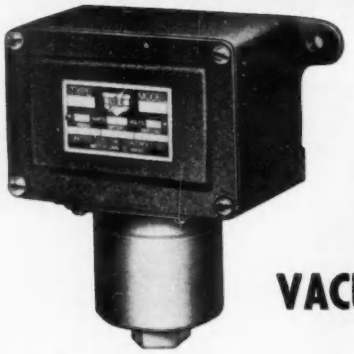

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Switch Differential	Fixed as specified between limits of 3" WC to 2 PSI.
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Weight	Approx. 1 lb. 8 oz.
Electrical Connection	½" NPT conduit opening in enclosure, screw type terminals on switch is standard.
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BULLETINS AND CATALOGS

The first four items in this section represent especially useful examples of applications literature. Direct request to the manufacturer is required for the first and fourth items, and a charge is made for them.

Relay and switch handbook

This plastic ring bound volume contains over 86 pages of textbook information useful to the engineer applying relays and switches. Tab indexed sections cover relay definitions, relay and switch theory, and circuit examples. This last section covers applications of a pulsing generator, time delays, and flip-flops, among others, furnishing circuit diagrams and descriptions. Other sections cover reference information (symbols, contact forms) and specifications of the manufacturer's switch and relay line. Price $1.—Electronetics Div., North Electric Co., Galion, Ohio.

Level, pressure control

A technical paper, this 12-page Bulletin TM-7 gives a complete mathematical analysis of the dynamics of level and pressure control. Basic control loops are diagrammed and transfer characteristics derived.—Fisher Governor Co. Circle No. 401.

Control valves

This exceptionally well illustrated, 32-page Bulletin 70-275 furnishes a thorough investigation of valves for process control. Built around the manufacturer's Super 70 line, the clear drawings and straightforward text serve as background for varied valve applications.—Black, Sivalls & Bryson, Inc. Circle No. 402.

Industrial tubes

Although this 23-page booklet is slanted mainly toward practical maintenance of industrial tube devices, the basic theory and circuit design for ignitrons, thyratrons, and rectifiers are also featured. Extensive treatment is given to cooling requirements of ignitrons. Price: $0.25.—National Electronics, Inc., Sub. of Eitel-McCullough, Inc., Geneva, Ill.

FOR QUICK REFERENCE. American Electronics, Inc., Instrument Div. Catalog, 6 pp. Foldout form gives fundamental engineering data on 200 resolvers and synchros in a manner intended for quick reference. Each unit's 10 basic parameters are covered. Typical photographs, dimension drawings, and circuit diagrams are also included. Circle No. 403.

DIGITAL MODULES. Computer Control Co., Inc. Catalog H, 12 pp. Following a preface consisting of a technical paper describing logic characteristics, this catalog gives detailed descriptions, electrical specifications, and functional diagrams of the manufacturer's line of 10 and 16-Mcps high speed, plug-in digital modules. Power supplies, and other accessories are included. Circle No. 404.

WEIGHT SENSING MANUAL. The Exact Scale Co. Form 3513, 8 pp. Reference booklet shows how principle of

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Panel space 144 x 144 mm (5¾ x 5¾ ins.)

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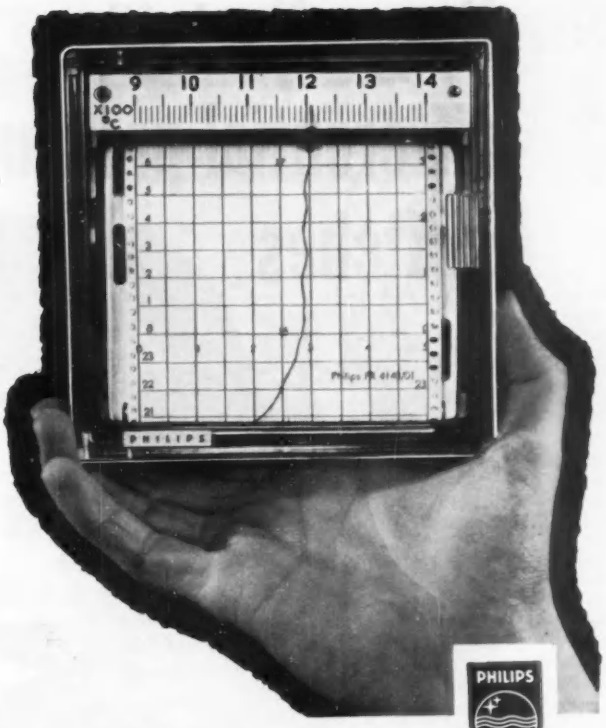

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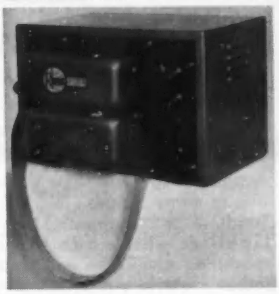

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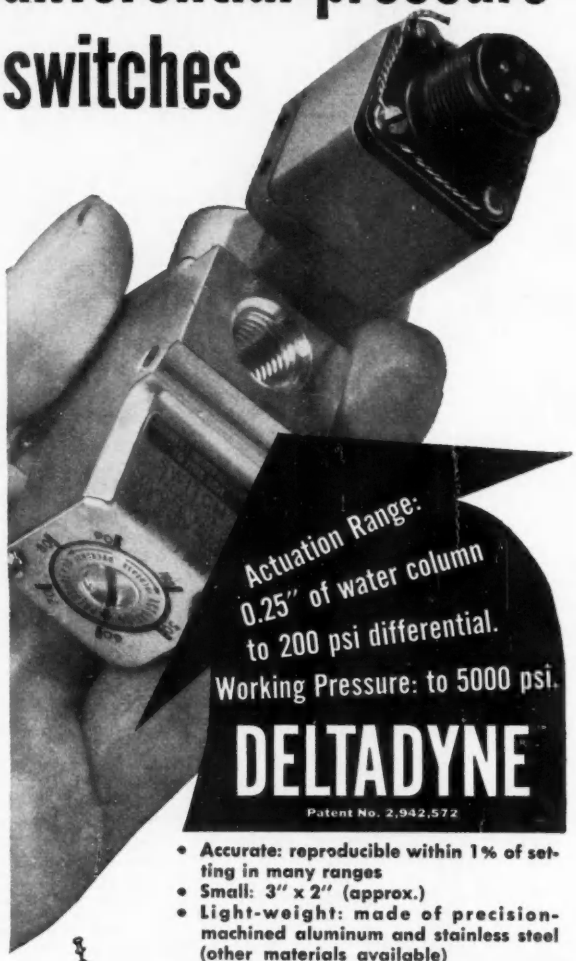

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This amazing switch, useful for pressure or differential pressure, combines advantages and economy not previously available in fluid system warning devices. Pressure may be adjusted in the field on a direct-reading dial. At set pressure, switch actuates to sound alarm, light bulb, turn motor on or off, or operate valve—in place or at remote panel board. Most models are not damaged by overpressures up to rated working pressure.

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Bulletins and Catalogs

weight sensing can be used in a wide variety of production and quality control applications. Describes manufacturer's Shadograph scale principle of weight sensing. Block diagrams show how weight classification and counting signals can be used for controlling process equipment and as input to data recording systems. Circle No. 405.

TUNNEL DIODE CIRCUITS. Transitron Electronic Corp. Booklet AN-1359A, 16 pp. Circuit design handbook contains sections on theory of tunneling action, various circuit considerations, and simple switching circuits. Functions include OR, AND, and majority gates. Four common digital circuits including shift register, ring counter, binary counter, and memories are described. Circle No. 406.

MATERIALS HANDLING. General Electric Co. Bulletin GEA-7130, 8 pp. Fully illustrated booklet, primarily for management, explains company's concept of automated material control. A section is devoted to explaining the part data processing might play in an automatic handling system. Five major functions of these systems—identification, dispatching, storage, recall, and delivery—are described and illustrated. Circle No. 407.

CONDENSED CONTROLLER DATA. Fenwal, Inc. Catalog MC-203, 8 pp. This condensed catalog gives brief descriptions and specifications for seven types of temperature controls. Brochure is designed as a handy reference tool. Details are included on 12 models of Thermoswitch units, six miniature local controls, four overheat detectors, four snap-action controls, and seven electronic controllers. Circle No. 408.

SIZE 8 FAMILY. Kearfott Div., General Precision, Inc. Catalog, 10 pp. Describes manufacturer's complete line of Size 8 components for missile and aircraft servosystems. Included are synchros, resolvers, servomotors, stepper motors, potentiometers, alternators, gear heads, clutches, and tachometer generators. Tables of specifications are given for each model and detailed dimension drawings are included, as well as performance curves for some units. Circle No. 409.

FLEXIBLE MICROWAVE. Lynch Communications Systems, Inc. Bulletin, 12 pp. Covers the LMR-20 6-kMcps system, a low cost flexible transmission medium for telephone, telegraph, teleprinter, protective relaying and telemetering, supervisory control, metering, and data communications. A microwave system consists of RF and multiplexing equipment and necessary antennas, towers, buildings, etc. Bulletin illustrates equipment and gives picture representation of typical applications. Circle No. 410.

SQUEEZE ON PROFITS. Bendix Computer Div. Report, 6 pp. Describes how advanced mathematical techniques and a high speed computer can be used to reduce overhead cost, excess inventories, and production waste for manufacturers, by allowing optimum plant utilization. A dynamic model for optimizing a manufacturing process is given with block diagrams. Also covered are sales forecasting,

requirements determination, and production scheduling. Circle No. 411.

PRECISION SWITCHES. Micro Switch, Div. of Minneapolis-Honeywell Regulator Co. Catalog 104, 24 pp. Covers representative selection of manufacturer's line of precision switches for industrial commercial data processing and airborne applications. Units are described by dimensioned photographs and tables of characteristics. Many special types are covered, including lighted pushbuttons and proximity switches. Circle No. 412.

CONTROLS FOR FLIGHT. United Control Corp. Catalog, 64 pp. Wide variety of control units and systems for airborne applications is covered in this well illustrated catalog. Units are classified as environmental, flight and propulsion, and temperature controls, and as accessory systems and components. Circle No. 413.

PRODUCT LINE DESCRIPTIONS. Midwestern Instruments, Inc. Product Digest No. 160. Booklet includes pictures and brief descriptions of manufacturer's line of electronic data handling equipment. Included are wet process and direct reading oscillographs, ground station telemetry instruments, and instrumentation tape handling gear. Circle No. 414.

HANDY CALCULATION AID. Micro Gee Products, Inc. Nomograph, 1 page. Rapid determination of rate in degrees per second and acceleration in degrees per second^2 when frequency in cps and displacement in degrees are known for rate gyros and angular accelerators is made possible by this useful nomograph chart. Circle No. 415.

SPECTROPHOTOMETERS. Scientific and Process Instruments Div., Beckman Instruments, Inc. Bulletin 735-B, 16 pp. Describes series of double beam ratio recording DK spectrophotometers. Well illustrated two-color publication includes diagram illustrating principle of operation and recordings of spectra. Full table of specifications and a partial bibliography are included. Circle No. 416.

PIEZOELECTRICITY. Clevite Electronic Components. Booklet, 16 pp. Illustrated publication highlights new developments in high power handling abilities of piezoelectric materials in describing applications of these devices. Comparison of the performance characteristics of all major piezoelectric substances is given. Tables cover piezoelectricity applied to conversions of mechanical to electrical energy, and vice versa. Circle No. 417.

PNEUMATIC CONTROL. Reliance Electric and Engineering Co. Bulletin G-2500, 16 pp. Concise descriptions and drawings of pneumatic control devices show how they may be applied to control liquid level, line pressure, process temperature, flow, steam pressure, and motor loading. Automatic pressure control systems may be manual remote, automatic open-loop, automatic closed-loop, and multiunit. Circle No. 418.

FRACTOMETER DATA. Perkin-Elmer Corp. Application data sheets PVP-AP-001/015-60. This series of application sheets provides information on using the manufacturer's process vapor fractometer in various chemical and petroleum processes. A general description of each process is given with details on the analysis

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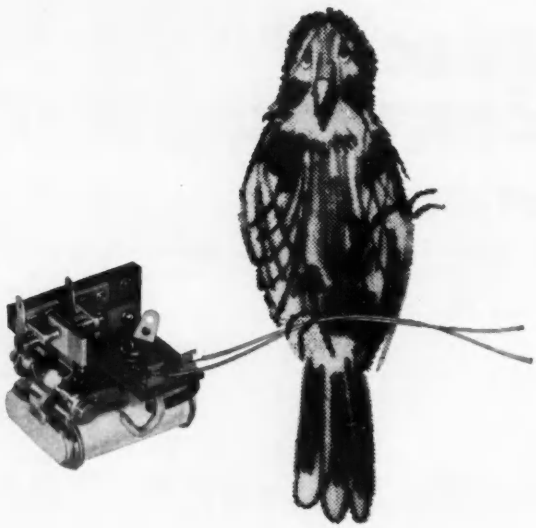

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that can be made by the fractometer and a list of accessory components that should be used. Among the processes covered are alkylation reactors, debutanizers, depropanizers, ammonia plants, and sulfur plants. Circle No. 419.

EXACT MOTOR CONTROL. Skiaky Bros., Inc. Bulletin No. 343, 4 pp. Describes Sciakydyne zero-error motor control for use where regulated speed and exact positioning are required. Block diagrams, photographs, and performance graphs show how the control turns a dc motor into an accurately controlled servomechanism and provides a direct link between an ac power source and a dc motor. Circle No. 420.

TORQUE MEASURING. Power Instruments, Inc. Brochure, 12 pp. Introductory section covers definitions and equations for torque, power, and efficiency testing Publication then continues with illustrated setups and recommendations for testing motors, gear trains, servomechanisms, and potentiometers. Typical curves are included. Circle No. 421.

AUTOMATIC REMOTE CONTROL. Moore Associates, Inc. Bulletin, 2 pp. Covers manufacturer's MARC Series of digital supervisory control and telemetering systems. Broad subject of automatic remote control in general is covered as well as five specific systems applications. Circle No. 422.

THERMOSTATIC SWITCHES. Thomas A. Edison Industries, Instrument Div. Bulletin No. 3009C, 8 pp. Describes two models of sealed thermostats: the Sl-1A glass unit and the 202 metal unit. A rundown on thermostat nomenclature is included, and complete specifications and design data with performance curves are given. Circle No. 423.

FULL MOTOR LINE. Reliance Electric & Engineering Co. Bulletin B-2515. Full color booklet pictures and describes line of ac motors, available in ratings from 1 to 2,000 hp, in form for easy selection of proper model. Also covered are production facilities and procedures. Circle No. 424.

MAGNETIC COMPONENTS. Arnold Magnetics Corp. Catalog, 20 pp. Covers manufacturer's line of miniature toroidal transformers, inductors, magnetic amplifiers, and other magnetic devices. Technical descriptions are supplemented by dimension drawings, circuit diagrams, photographs, and curves. Circle No. 425.

RIGHT-ANGLE GEARMOTOR. U. S. Electrical Motors, Inc. Brochure F-1971, 6 pp. Ratings and dimensional data for a line of worm-gear right-angle motors is given in tabular form in this two-color folder. Large cutaway drawings and diagrams of mounting and assembly positions are also included. Circle No. 426.

HIGH EFFICIENCY SUPPLIES. Valor Instruments, Inc. Catalog PS 361, 16 pp. Technical article describing the switching preregulator method of voltage regulation in solid state power supplies leads off this catalog, which covers a line of compact, highly regulated dc supplies. Feature of the supplies is efficiency of 80 percent, achieved through the preregulation technique. Photographs and specifications are included for modular, rack, and cabinet units. Circle No. 427.

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313	324	335	346	357	368	379	390	401	412	423	434	445	456	467	
314	325	336	347	358	369	380	391	402	413	424	435	446	457	468	
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469	
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470	
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REPRINTS

474	485	496	507
475	486	497	508
476	487	498	509
477	488	499	510
478	489	500	511
479	490	501	512
480	491	502	513
481	492	503	514
482	493	504	515
483	494	505	516
484	495	506	517

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Index of advertised equipment, new products, and bulletins. For additional information circle number on card corresponding to number to left of item.

1. SYSTEMS

Advertisements

9—Process control systems, p. 8
48—Computer process control, p. 48
53—Inertial guidance systems, p. 53
66—Data gathering, display, computing-control, p. 66
155—Packaged hydraulic control, p. 155
173—Electronic instrumentation, p. 173
180—Reactive missile controls, p. 180
193—Speed, position control, p. 193
223—Computing systems, 2nd cover

Bulletins and Catalogs

407—Materials handling system, p. 192
410—Microwave data, control links, p. 192
411—Computer for business problems, p. 192
418—Pneumatic control systems, p. 193
422—Remote supervisory control, p. 194

2. DATA HANDLING AND DISPLAY EQUIPMENT

Advertisements

2—Timing code generator, p. 2
5—Versatile digital printer, p. 5
11—Flexible 24-point recorder, p. 11
16—High density tape recorder, p. 16
17—Wide band recorder, p. 17
26—Precision volt, frequency meters, p. 26
30—Direct writing oscillograph, p. 30
37—Data communications center, p. 37
40—High resolution oscillograph, p. 40
46—Shaped beam tube, p. 46
52—Random access storage and display, p. 52
54—Automatic punched tape preparation equipment, p. 54
62—Paper tape perforator, p. 62
67—Compact instrumentation tape recorder/reproducer, p. 67
69—Decimal readout tubes, p. 69
72—Printer-perforator combination, p. 72
107—FM magnetic tape system, p. 107
140—Compact process recorder, p. 140
142—High speed magnetic counter, p. 142
154—Time code generators, p. 154
156—Noise-free output recorder, p. 156
160—High speed printers, p. 160
169—Keyboard digital printers, p. 169
188—Direct writing recorder, p. 188
189—Small, but readable, gages, p. 189
225—Compact recorder/reproducer, 4th cover
228—Miniature strip recorder, p. 191
235—In-line digital readout, p. 210

New Products

309—Production data gatherer, reader, p. 151
310—NC tape checker, p. 152
311—Selective erase display tube, p. 152
312—Multipoint strip chart recorder, p. 152
313—Fiber optic CRT, p. 152
314—PE paper tape reader, p. 154
315—Portable tape printer, p. 154
316—Printed motor tape reader, p. 156
317—Telemetering A/D converter, p. 156
318—Measurement meter, p. 156

Bulletins and Catalogs

414—Data handling product line, p. 193

3. RESEARCH, TEST, AND DEVELOPMENT EQUIPMENT

Advertisements

1—Voltage standard and null voltmeter, p. 1
49—Constant output generator, p. 49
56—Ac signal measuring instruments, p. 56
57—Analog to frequency converter for automatic checkout, p. 57
76—DVM, analog X-Y plotter, p. 76
108—Portable null-balance pot, p. 108
120—DVM with reed relays, p. 120
185—Thermal conductivity analyzer, p. 185
186—Absolute pressure gages, p. 186
202—Power transistor test set, p. 202
209—Wheatstone bridge, meter, p. 209
211—Waveform analyzers, p. 211
222—Digital pressure generator, p. 222

New Products

319—Commutator simulator, p. 156
320—Resolver function bridge, p. 158
321—Time interval counter, p. 158
322—Servosystem checkout unit, p. 159
323—Thermistor monitor and alarm, p. 159
324—Size 9 potentiometer, p. 159
325—Servo analysis unit, p. 159
326—3-in. rectangular screen 'scope, p. 159

Bulletins and Catalogs

416—Spectrophotometer data, p. 193
419—Fractometer applications, p. 193
421—Torque measurement guide, p. 194

4. PRIMARY ELEMENTS AND TRANSDUCERS

Advertisements

38—Floated integrating gyro, p. 38
41—Strain gage pressure pickup, p. 41
44—Microminiature thermocouple, p. 44
65—Two-gyro inertial platform, p. 65
153—Temperature detectors, monitors, p. 153
158—Two-speed synchro, p. 158
159—Pancake synchro transmitter, p. 159
163—Ultrasonic level sensors, p. 163
184—A/D converting shaft pickup, p. 184

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187—Plunger metering pump, p. 187
199—Precise angle indicator, p. 199
204—Stable load cells, p. 204
224—Pancake synchro line, 3rd cover
227—Shaft position encoders, p. 183
234—Bellows pressure sensors, p. 209
236—Resistance thermometers, p. 210
239—Sensitive transducer, p. 214

New Products

327—Top, side light sensitive cell, p. 159
328—1-volt output load cells, p. 159
329—Stress-strain gage, p. 160
330—Differential refractometer, p. 160
331—Compact dc tachometer, p. 160
332—Transmitting rotameters, p. 162

Bulletins and Catalogs

403—Resolver, synchro data, p. 190
405—Weight sensing units, p. 190
415—Calculation aid for rate gyros, angular accelerometers, p. 193
417—Piezoelectricity background, p. 193

5. RELAYS, SWITCHES, AND CONTROLLERS

Advertisements

14—Reliable relay models, p. 14
23—Compact 300-volt relay, p. 22
35—Pressure switches for rough environments, p. 35
55—Motion sensing element, p. 55
64—Versatile temperature controller, p. 64
75—Sealed limit switch, p. 75
97—Versatile controller-recorder, p. 97
98—Long-lived stepping switch, p. 98
115—Mechanically held relays, p. 115
133—Control panel precision switches, p. 132
144—Customized relay series, p. 144
167—Space-saving 4-pdt relay, p. 167
168—Pneumatically timed delay relays, p. 168
172—Sealed contact reed relays, p. 172
174—One to 12-pole reed relays, p. 174
182—Sensitive meter-relay, p. 182
190—Pressure, vacuum control, p. 190
194—Experience-proven relay, p. 194
221—Hg-to-Hg contact relays, p. 221
231—Teflon bearing mercury relay, p. 206
232—Punched card sensing switch, p. 206
238—Ultrasensitive relays, p. 213

New Products

333—Liquid level controller, p. 162
334—Computer mercury contact relay, p. 162
335—Solid state relay, p. 165
336—Compact valve controller, p. 165
337—Proximity switch designed to sense all metals, p. 165

Bulletins and Catalogs

401—Level, pressure control dynamics, p. 190
408—Temperature control lines, p. 192
412—Selection of precision switches, p. 193
413—Airborne control devices, p. 193
420—Zero-error motor control, p. 194
423—Sealed thermostatic switches, p. 194

6. POWER SUPPLIES

Advertisements

71—Transistorized regulated units, p. 70
146—Supply for voltage sensitive gear, p. 146
213—Eight-position rotary switches, p. 213
230—Ultrastable regulated supply, p. 206

ADVERTISEMENTS *Mail Before August 1, 1961*

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474	485	496	507
475	486	497	508
476	487	498	509
477	488	499	510
478	489	500	511
479	490	501	512
480	491	502	513
481	492	503	514
482	493	504	515
483	494	505	516
484	495	506	517

Name *Title*

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Address *City* *Zone* *State*

New Products

338—Fast switchover standby unit, p. 165
339—Overvoltage protected supplies, p. 165
340—Emergency computer power, p. 166
341—Regulated laboratory source, p. 166

Bulletins and Catalogs

427—High efficiency dc supplies, p. 194

7. ACTUATORS AND FINAL CONTROL ELEMENTS

Advertisements

10—High powered solenoids, p. 10
24—Reversible action valves, p. 24
28—Line of rotary valves, p. 28
78—Size 8 servomotor, p. 78
136—Valve for cryogenics, p. 136
148—High pressure control valve, p. 148
171—Actuator, valve combinations, p. 170
177—Versatile control valves, p. 177
183—Reliable electrohydraulic valve, p. 183
201—400-cps synchronous motors, p. 201
205—Digital actuator line, p. 205
229—Size 5-18 servomotors, generators, p. 204

New Products

342—Accurate pneumatic positioner, p. 168
343—Miniature, high performance electro-hydraulic servovalve, p. 168
344—High rotor-impedance servomotor, p. 172
345—53-percent efficient dc motor, p. 172

Bulletins and Catalogs

402—Process control valves, p. 190
424—Many size motors, p. 194
426—Right-angle worm-gearmotor, p. 194
(Continued on p. 199)

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3	17	31	45	59	73	87	101	115	129	143	157	171	185	199	213	227	241	255	269	283	297
4	18	32	46	60	74	88	102	116	130	144	158	172	186	200	214	228	242	256	270	284	298
5	19	33	47	61	75	89	103	117	131	145	159	173	187	201	215	229	243	257	271	285	299
6	20	34	48	62	76	90	104	118	132	146	160	174	188	202	216	230	244	258	272	286	300
7	21	35	49	63	77	91	105	119	133	147	161	175	189	203	217	231	245	259	273	287	301
8	22	36	50	64	78	92	106	120	134	148	162	176	190	204	218	232	246	260	274	288	302
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10	24	38	52	66	80	94	108	122	136	150	164	178	192	206	220	234	248	262	276	290	304
11	25	39	53	67	81	95	109	123	137	151	165	179	193	207	221	235	249	263	277	291	305
12	26	40	54	68	82	96	110	124	138	152	166	180	194	208	222	236	250	264	268	292	306
13	27	41	55	69	83	97	111	125	139	153	167	181	195	209	223	237	251	265	269	293	307
14	28	42	56	70	84	98	112	126	140	154	168	182	196	210	224	238	252	266	280	294	308

NEW PRODUCTS & BULLETINS

309	320	331	342	353	364	375	386	397	408	419	430	441	452	463	
310	321	332	343	354	365	376	387	398	409	420	431	442	453	464	
311	322	333	344	355	366	377	388	399	410	421	432	443	454	465	
312	323	334	345	356	367	378	389	400	411	422	433	444	455	466	
313	324	335	346	357	368	379	390	401	412	423	434	445	456	467	
314	325	336	347	358	369	380	391	402	413	424	435	446	457	468	
315	326	337	348	359	370	381	392	403	414	425	436	447	458	469	
316	327	338	349	360	371	382	393	404	415	426	437	448	459	470	
317	328	339	350	361	372	383	394	405	416	427	438	449	460	471	
318	329	340	351	362	373	384	395	406	417	428	439	450	461	472	
319	330	341	352	363	374	385	396	407	418	429	440	451	462	473	

REPRINTS

474	485	496	507
475	486	497	508
476	487	498	509
477	488	499	510
478	489	500	511
479	490	501	512
480	491	502	513
481	492	503	514
482	493	504	515
483	494	505	516
484	495	506	517

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Equipment Index

(Continued from page 197)

8. COMPONENT PARTS

Advertisements

7—Industrial silicon transistors, p. 7
15—Pneumatic control elements without moving parts, p. 15
45—Flexural pivot bearing, p. 45
50—Temperature controlled memory, p. 45
51—Analog computer multiplier plug-in units, p. 51
61—Solid state 100-watt dc amp, p. 61
63—Series regulator tube, p. 63
80—Military transistor line, p. 80
82—Trimmer potentiometers, p. 82
150—50-amp SCR's, p. 150
157—Pin connector line, p. 157
165—Germanium power transistors, p. 164
191—Tape reader, shaft pickup, p. 191
206—Compact logic panels, p. 206
214—Varied lens line, p. 214
226—Reliable transformers, p. 154
237—Plug and jack assemblies, p. 212

New Products

346—Limit stop assembly, p. 174
347—Computer amplifier package, p. 174
348—Nonambiguous storage drum, p. 176
349—Right or left shift register, p. 176
350—Ultraminiature sealed diode, p. 179
351—Operational amplifier, p. 179
352—MIL-spec memory drums, p. 179

Bulletins and Catalogs

404—10, 16-Mcps digital modules, p. 190
406—Tunnel diode theory, circuits, p. 192
409—Units available in Size 8, p. 192
425—Line of magnetic devices, p. 194

9. ACCESSORIES AND MATERIALS

Advertisements

6—Heatless instrument air dryer, p. 6
20—Instrumentation tape, p. 20
152—Automatic spectrum equalizer, p. 152
162—Thermocouple alloys, p. 162
175—Ni-Span C Bourdon tubing, p. 175
179—Precise chart papers, p. 178
200—Custom chart papers, p. 200
207—Desk calculator, p. 207
208—Rack mounting kits, p. 208
212—Cooling system scoop, p. 212

New Products

353—Chromatograph programmer, p. 179
354—Thermoelectric spot coolers, p. 179
355—Static fault alarm, p. 179
356—Two-channel operation monitor, p. 180
357—IR spectrometer accuracy control, p. 180

CONTROL BITS

New computer process control combination has been announced by IBM. The 1710 control system, the first variable word length process control computer, consists of the new 1711 data converter and the 1620 computer. The converter scans up to 300 analog signals at five per sec, has a four decimal-digit A/D converter. Analog ranges are changed by switching plugin cards.

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The new CO 2721011 Precise Angle Indicator features an accuracy of ±6 minutes. Latest addition to the Kearfott line of standard test equipment, the unit is designed to meet a wide range of applications. Typical Applications • Indication of gyro angle of pitch, roll, or yaw and relaying of signal to any preselected impedance or voltage level. • Indication of shaft position of remote synchro or resolver, and transmission of this information to any impedance or voltage level. • Display of difference between two shafts when driven by transmitter and differential synchros.

In addition to high accuracy the instrument combines a number of other prominent advantages: it requires only a single power source; it has good sensitivity; it is designed for modular application; and it offers direct automatic readout. The unit is of extremely compact construction and is built for maximal ease of maintenance.

The low-cost CO 2721011 Precise Angle Indicator is available with a single sensor, auxiliary dual-input sensor, or an auxiliary retransmitter. For additional information on this new test instrument, write for the brochure which describes its operation and capabilities in detail.

SPECIFICATIONS

Repeatability	±1.2 min	**Slewing Speed**	7 sec/180°
Readability	0.5 min	**Power (single source)**	115 v, 1φ, 400 cps
Input Power	30 va	**Size**	1¾ x 9½ x 9⅛ in.
Sensitivity	1.0 min	**Weight**	4 lbs.

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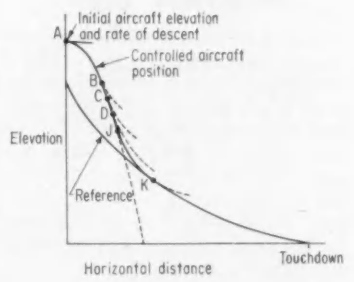
ABSTRACTS

How predictive control works

From "Predictive Control System Application", by H. Chestnut, W. E. Sollecito, and P. H. Troutman. Presented at the American Institute of Electrical Engineers Winter General Meeting, New York, N. Y., Jan. 29-Feb. 3, 1961.

Predictive control is a form of automatic control in which the manipulated variable operating the controlled system is actuated by estimate of the error that will exist at some future time. Repeated estimates of future error are obtained by predicting both the reference and the controlled variable, as well as some of their lower order derivatives, on a fast-time basis. Predictive control systems are similar to nonlinear optimum switching systems in that they control the polarity of an actuating signal so that the output of a plant or other controlled system synchronizes with a given actuating signal polarity until such time that the predicted error and error rate reach zero together. Then the signal polarity is reversed.

The figure shows a controlled aircraft landing. At point A, the aircraft is above the reference path and descending too slowly. The control logic immediately calls for a negative polarity actuating signal, causing the aircraft to follow the trajectory shown. The dashed curve proceeding downward from J indicates the trajectory in the event that the polarity remains negative. At point B, where the error and the error rate become of opposite polarity, the fast-time model determines the trajectory in the event of polarity reversal at that time. Since this trajectory, indicated by the dashed curve starting at B, does not intersect the reference where the predicted error rate equals zero, this is not the proper time to switch. A second prediction is made at C with the same conclusion. The prediction is repeated until finally at J the predicted error and the error rate reach zero



together. The trajectory then follows the solid curve to K, and beyond that a small hunting exists.

Because maximum actuation signal is used, the maximum force capabilities of the controlled system are used to remove initial condition errors and disturbance effects. The conventional stability criteria do not seem to be a major consideration. Rather, the basic limitation lies in the speed of computation and in the accuracy of measurement of present conditions.

A major disadvantage of this form of control lies in the need for a fast-time simulator and fairly elaborate control logic. A trade-off must be made between rapid, accurate response and equipment complexity. The simulator may be either analog or digital. The analog approach offers economy, small size, reliability, and fast response. The digital approach offers accuracy and is most practical when the computer is used for other purposes.

The logic described in this paper uses a variable frequency repetition rate—highest when the controlled variable is close to the command signal—for prediction. This improves response and accuracy of the system.

The model need not be an exact replica of the plant to provide good control. Time constants and gains can be in error by 2 to 1 and more without excessive loss of performance. In general, to avoid overshoot, the fast-time model should be made to simulate a system slower than the actual controlled system. When approximating higher order systems with a lower order model, the model is more effective when its most dominant time constant is proportional to the sum of the time constants in the higher order controlled system.

Pressure measuring elements

From "Bibliography on Diaphragms and Aneroids", edited by L. M. Van der Pyl, Rockwell Manufacturing Co. Paper No. 60-WA-122 presented at the Winter Annual Meeting of the American Society of Mechanical Engineers, New York City, Nov. 27-Dec. 2, 1960.

Accumulating 171 outstanding papers and other literature on diaphragms and aneroids, 14 volunteer reviewers joined under the chairmanship of Dr. H. J. Grover to produce this annotated bibliography. Listed alphabetically by author, each paper is described by an abstract averaging about five lines. This present bibliography updates a previous one: ASME paper 55-WA-180.

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Size	Part Number	Synchronous Speed	No. Phases	Pull-Out Torque
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8	M172-02	8000 rpm	2	0.28 in. oz.
8	CM4 0172-001	8000 rpm	3	0.31 in. oz.
11	R172-001	8000 rpm	2	0.42 in. oz.
15	T170-001	8000 rpm	2	0.78 in. oz.
18	MK 6 Mod 1	8000 rpm	3	2.2 in. oz.
23	Z1360-002	8000 rpm	3	16.0 in. oz.

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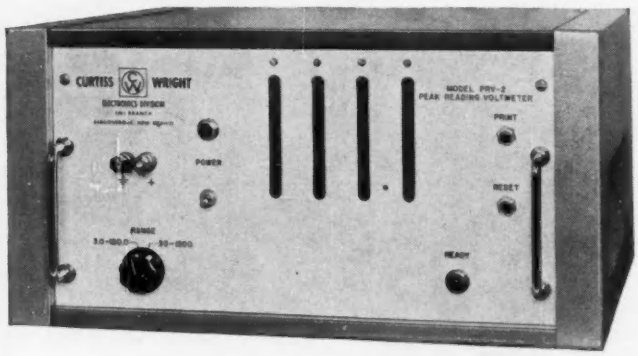

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NEW BOOKS

Analog Computer Math

ANALOGUE COMPUTERS. *I. I. Eterman.* 264 pp. *Published by Pergamon Press, Inc., New York.* $8.50.

This translation (a very good one) of a recent work by a Russian computer expert gives the reader an opportunity to learn the Russian approach to both analog computation and analog computer design. It is probably the only analog computer book ever written for mathematicians instead of engineers. The author emphasizes this in his preface when he says that his book is devoted to the mathematical aspects of analog computer theory because it is this area that is the most important and has been the most neglected.

Chapter I deals with the mathematical theory of dynamic systems. Chapter II describes the building blocks of both mechanical and electronic analog computers. The author's technique for simulating a function of many variables using only single-input function generators and electronic multipliers is of particular interest. The mathematics is quite involved at this point, but the idea is simply to approximate a function of many variables by a series containing the sums or products of functions of one variable. Several carefully worked out examples help clarify the principles involved. Some circuits for generating nonlinear characteristics are discussed.

The first part of Chapter III describes some Russian analog computers. The second part is an explanation of machine operational procedures. In addition to the usual discussion of machine setup, variable scaling, and time scaling, the author has appended about fifteen sets of differential equations, with worked out solutions and tables of variables vs. time. This novel feature enables the computer operator to estimate accuracy by comparing the machine solution with the exact solution for a wide variety of dynamic systems. These systems range from a simple harmonic generator to a system of ten simultaneous differential equations with variable coefficients, providing great flexibility in verifying computer accuracy.

Chapter IV discusses the analog computer solution of linear differential equations, algebraic equations, boundary-value problems, and the method of finite differences. The appendix to the chapter contains a very

elaborate compilation of derivatives in terms of various difference formulas in table form, useful when solving partial differential equations on an analog computer. Chapter V covers methods for estimating the errors in analog computer solutions of dynamic systems. In this area, the Russians apparently use Lyapunov's Second Method for the error analysis of nonlinear systems and some new theoretical treatments for the error analysis of linear systems. This is the first book I have ever seen that deals with this topic at great length. Judging by the scarcity of published American literature on this subject, it would seem that the Russians are ahead of us in this area where further research is vitally needed.

This remarkable book is *not* recommended for engineers and casual mathematicians. It is highly recommended for mathematicians working intimately on analog computers and problem setup.

Leslie Axelrod
The Powers Regulator Company

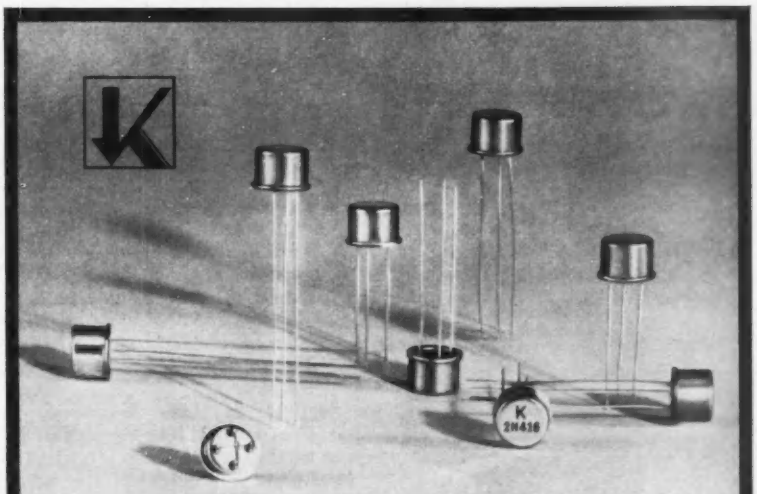
Data recording

MAGNETIC TAPE INSTRUMENTATION. *Gomer L. Davies, 272 pp. Published by McGraw-Hill Book Co., Inc., New York.* $8.50.

Not a treatise on how to design magnetic tape hardware, this is an up-to-date guide to the purchase, use, and application of tape equipment for data recording and reproduction.

After a very brief history and just enough of the fundamentals of magnetic recording for background, there is a lengthy chapter on the many modulation techniques used in recording analog and digital signals. A section on transport mechanisms leads into a discussion of tape motion irregularities — flutter and skew. The electronic and mechanical means of compensating for these short-term variations are covered, as well as rate and positional servo techniques for keeping the average tape speed constant. There is a chapter on heads and multitrack head stacks, and one on magnetic tape systems. The latter discusses input and output translation devices, representative applications, and system limitations, and has an extensive applications bibliography. The final chapter describes magnetic drums and discs.

There is a minimum of mathematics in the text, but two appendixes contain hitherto unpublished analyses of the effect of flutter on FM carrier recording, and time displacement error due to tape speed variation.



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2N317	2N416	2N523	2N662
2N317A	2N425	2N523A	2N1017
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MEETINGS

MAY

Electronic Components Conference, sponsored by IRE, AIEE, EIA, Jack Tar Hotel, San Francisco, Calif. May 2-4

Institute of Radio Engineers, Second National Symposium on Human Factors in Electronics, Marriott-Twin Bridges Motor Hotel, Arlington, Va. May 4-5

Institute of Radio Engineers, 13th Annual National Aerospace Electronics Conference (NAECON), Miami and Biltmore Hotels, Dayton, Ohio May 8-10

Instrument Society of America, Fourth National Power Instrumentation Symposium, LaSalle Hotel, Chicago, Ill. May 8-10

The Material Handling Institute Conference and Show, Trade and Convention Center, Philadelphia, Pa. May 9-11

Western Joint Computer Conference, sponsored by IRE, ACM, AIEE, Ambassador Hotel, Los Angeles, Calif. May 9-11

International Exhibition of Measurement, Control, Regulation and Automation (MESUCORA), Exhibition Hall, Centre National des Industries et des Techniques, Paris, France May 9-17

Instrument Society of America, Pulp and Paper Instrumentation Symposium, Northland Hotel, Green Bay, Wis. May 10-12

American Institute of Industrial Engineers, 12th Annual National Conference and Convention, Sheraton Cadillac Hotel, Detroit, Mich. May 11-13

Fifth National Symposium of Global Communications (Globecom V), sponsored by AIEE, IRE, Hotel Sherman, Chicago, Ill. May 22-24

Tenth National Telemetering Conference, sponsored by IRE, AIEE, IAS, ARS, ISA, Sheraton-Towers Hotel, Chicago, Ill. May 22-24

Symposium on Large Capacity Memory Techniques for Computing Systems, sponsored by Information Systems Branch of Office of Naval Research, Department of Interior Auditorium, Washington, D. C. May 23-25

JUNE

Instrument Society of America, Summer Instrument-Automation Conference and Exhibit. Royal York

(Continued on page 207)

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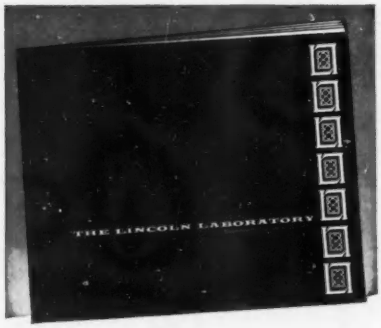

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SETTING THE PACE

by Arthur L. Fitch
President
Pace Controls Corp.

ONE WAY TO MEET THE TREND TOWARD DIGITAL CONTROL

Pace Control's reason for being is based on a firm belief in the future of the automatic control industry. As we see it, our function is to provide means for accomplishing complex operations, efficiently and accurately, where manual or semi-manual skills are not adequate — or may not even be possible. We see it as our function, too, to provide a release from the tedium of repetitive operations. This is our governing philosophy and the reason behind this series of articles I've called "Setting The Pace".

Concurrent with our approach toward the control industry, we recognize that the demands of this era of industrial revolution for technical apparatus — and its control — are compounding themselves with each passing year.

Already, a decided trend toward the digital approach in the electronics industry is evidenced in the swing from devices that have been analog toward conversion to digital. This would include just about everything from computers to voltmeters. What's the explanation for this trend? It could be found quite possibly in the mounting demand for versatility, reliability and simplicity.

Now, if automatic control, particularly electronics, is to enjoy a boundless future, — and if the approach to electronic control devices is to lean more heavily on the digital approach, doesn't it seem logical to conclude that digital control, indeed, is a business with a future? We think so.

And it follows, with equal logic, that if the trend is toward digital electronics in the form of computers, programmers, read-in and read-out devices and a myriad of other electronic devices, it can be safely assumed that digital apparatus will do the work.

To a large extent, without DIGITORK (which we'll tell you about shortly), this just isn't possible. Even now, a completely digital control system will eventually terminate in digital to analog conversion to do work with analog devices.

We believe that the *completely* digital approach cannot end at the input. Rather, it must eventually be carried through to the output — and where necessary — again back to the input for checking reference.

DIGITORK — first and only motor of its kind.

Of the many hundreds of devices that must rely on digital type signals for their control — or would certainly be better if they did — DIGITORK can provide the answer. Perhaps the only answer. You can be sure *we're* sure when we make a statement like that! DIGITORK, by the way, is our trade name for family of products centered around a unique stepping motor principle. Here, we have a digital, torque-producing actuator responding in discrete increments of motion . . . one step for each pulse. The concept of application in its rudest element is . . . a desired motion — rotary, linear or

other — may be accurately controlled by the *number* of pulse signals furnished. The speed of the motion may be accurately controlled by the *rate* at which the signals are delivered to the control. Certainly, there's much more to tell about DIGITORK than this, but we're getting too close to the bottom of the page. We expect you'll want to learn the whole exciting story, so write in and we'll have it on its way to you by return mail.

In any case, with acceptance of the DIGITORK principle gaining momentum at an encouraging rate, we at Pace Controls foresee a most promising future. As we see it . . .

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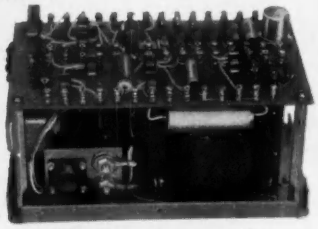

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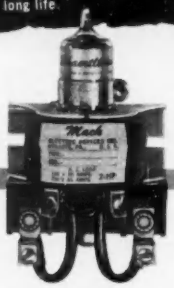

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*Du Pont trade name for Tetrafluoroethylene Resin

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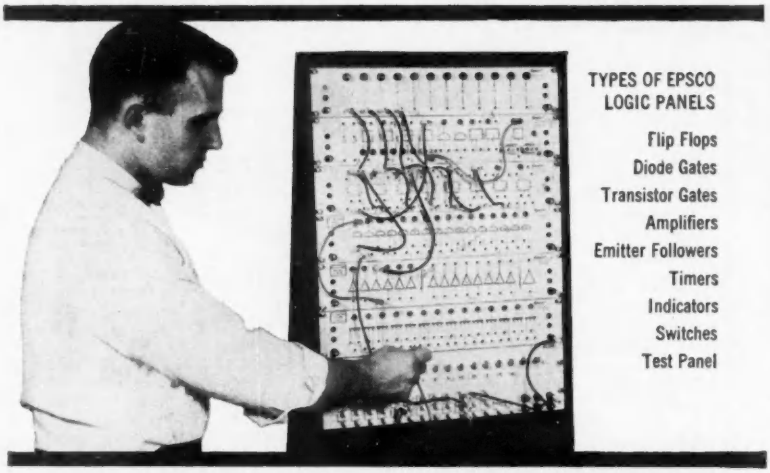

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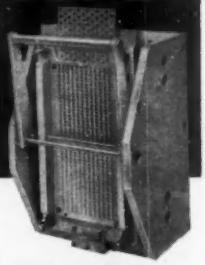

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MEETINGS

JUNE (*Continued*)

Hotel and Queen Elizabeth Hall, Toronto, Ontario, Canada June 6-8

Instrument Society of America, Third Biennial International Gas Chromatography Symposium, Kellogg Center, Michigan State University, East Lansing, Mich. June 13-16

Institute of Radio Engineers, Fifth National Conference on Product Engineering and Production, Sheraton Hotel, Philadelphia, Pa. June 14-15

Association for Computing Machinery, Computer Conference on Business Languages, Western Reserve University, Cleveland, Ohio June 15

American Institute of Electrical Engineers, Summer General Meeting, Willard Straight Hall, Cornell University, Ithaca, N. Y. June 19-23

Denver Research Institute of University of Denver, Eighth Annual Symposium on Computers and Data Processing, Elkhorn Lodge, Estes Park, Colo. June 22-23

Institute of Radio Engineers, Fifth National Convention on Military Electronics (MIL-E-CON 1960), Shoreham Hotel, Washington, D.C. June 26-28

Second Joint Automatic Control Conference, sponsored by IRE, ISA, AIEE, AIChE, ASME, University of Colorado, Boulder, Colo. June 28-30

JULY

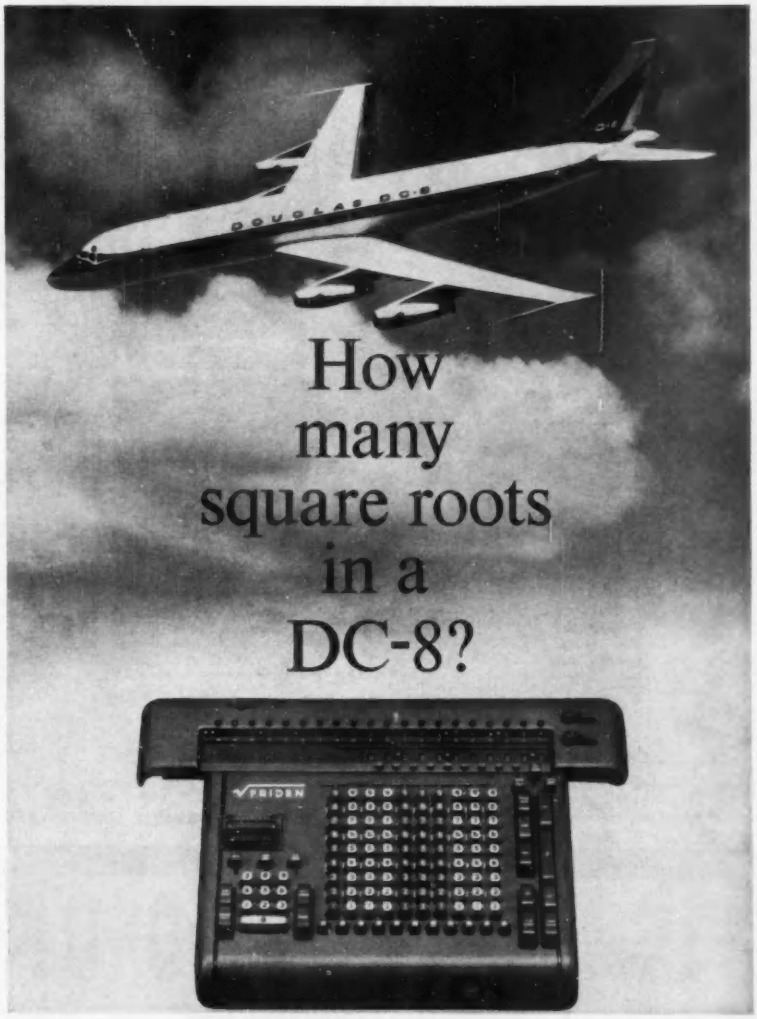
Gordon Research Conference on Scientific Information Problems in Research, New Hampton School, New Hampton, New Hampshire July 3-7

Fourth International Conference on Bio-Medical Electronics and 14th Conference on Electronic Techniques in Medicine and Biology, sponsored by ISA, IFME, AIEE, IRE, Waldorf-Astoria Hotel, New York City July 16-21

AUGUST

Gordon Research Conference on Instrumentation, Colby Junior College, New London, New Hampshire Aug. 14-18

Western Electronics Show and Convention (WESCON), sponsored by IRE and WCEMA, Cow Palace, San Francisco, Calif. Aug. 22-25



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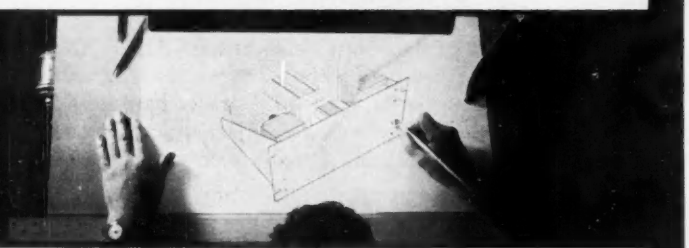

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The following reprints have been prepared to make important reference-type editorial material available to CONTROL ENGINEERING readers in convenient filable form. Single copies of any reprint can be obtained at the nominal cost listed below by circling the corresponding numbers on a reader service card, p. 195. Don't send money with card, we will bill you later. For multiple copies write Reprint Dept. Quantity rates will be quoted on request.

509—Applying Incremental Servos, 24 pp. Incremental servos offer many advantages in closed loop systems. A grouping of five basic articles compares stepping and stepless control, describes the operation and analysis of solenoid-ratchet and phase-pulsed synchronous steppers, shows 16 applications of stepping motors, tabulates pertinent characteristics of available stepping motors, and discusses the problems of interlocking the devices. 65 cents.

508—Transistor Switches for Industrial Service, March 1961, 24 pp. Industry requires reliable, inexpensive, and fast switching devices. This special report thoroughly covers one possible solution to this requirement—transistor logic modules packaged for industrial use. Topics include: how transistors perform logic functions, available systems and components, tips on selection and use, and case studies of industrial applications. 65 cents.

507—Tips on the Use of Electromechanical Relays, 24 p. Compilation of five articles presents practical information on the design, test, and use of relay control systems. Topics covered include: testing relay electrical reliability, improving system reliability, narrowing relay differential, logical synthesis of systems, and verifying relay control circuits. 65 cents.

506—What You Should Know About Adaptive Systems, 17 pp. Is there such a thing as an adaptive control system? What approaches have been taken? What does the future hold? These are the questions the author answers in this three-article reprint, in sufficient detail and with sufficient references to provide a basic grounding in this latest area of control engineer interest. 50 cents.

505—The Basics of Optimum Response Relay Servos, 17 pp. Three part series summarizes all of the important design techniques that have been used to optimize the response of relay servos. The reprint describes the development of the optimum switching criteria, and outlines

(*Continued on page 211*)

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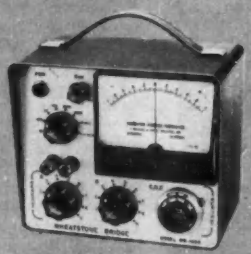

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504—System Characteristics of Modern Guidance Techniques, August 1960, 22 pp. In this special report five experts from three companies cover the system characteristics of inertial navigators, guidance radars, Doppler radar techniques, modern techniques in celestial navigation, and perceptive guidance systems. 65 cents.

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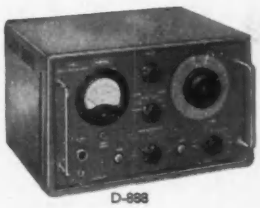
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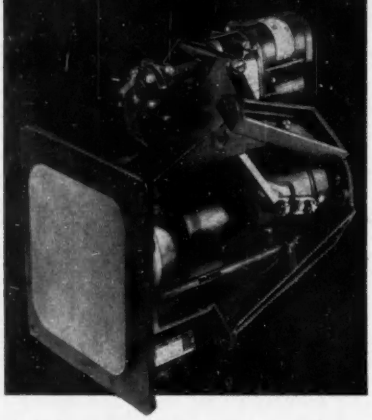

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494—How to Use the Root Locus in Control System Design, 12 pp. Another reprint that translates theory into practice. Eight simple rules make locus construction easy, even including the effects of distance-velocity lags. Articles show how to interpret the locus diagram, how to determine transient response, and how to use locus techniques with multiloop systems. 45 cents.

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488—A Roundup of Control System Test Equipment, 24 pp. Specialized control system test equipment divides into three classes: 1) devices that only generate a test signal, 2) systems that both disturb the system and provide a means for evaluating response, and 3) devices that only evaluate control system response. 60 cents.

487—Survey of Ac Adjustable-Speed Drive Systems, June 1959, 16 pp. Regarded as constant speed devices, multispeed ac actuators actually take many efficient forms. The recent resurgence of interest in these ac adjustable-speed systems prompted this comprehensive coverage of pole-changing techniques, armature resistance control of wound-rotor motors, frequency changing, slip-frequency injection, and the use of eddy-current couplings. 50 cents.

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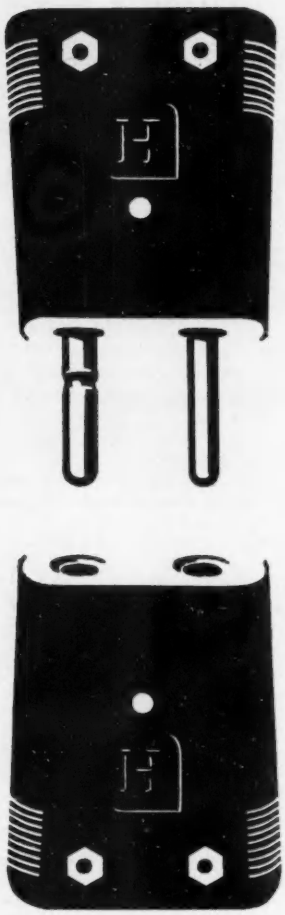
(Continued on page 214)



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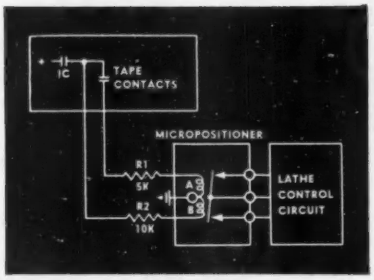

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8-POSITION ROTARY SWITCHES

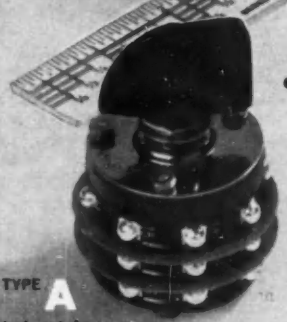
for industrial and military applications

TYPE **JL**

Manufactured to MIL-S-21604 and BuShips drawing 9000-S6202-74422

TYPE **AF**

Manufactured to specification MIL-S-6807A and drawing #MS25002 (ASG)



TYPE **A**

for industrial applications.

ALL THESE SWITCHES are small units designed for tap, transfer, or selector use at low current ratings. The construction of the Esco Types AF and JL switches is the same as the Type A switch except that they are manufactured with materials to meet applicable MIL Specifications and BuShips drawings.

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Type	Sections	Positions	Poles	Contacts	Indexing	Mounting	Electrical Ratings interrupting
A	1 to 10	2 to 8	1 to 20	nonshorting or shorting	45°	panel threaded bushing	5 amp., 120 volts a-c
AF	1 to 6	2 to 8	1 to 6	nonshorting only	45°	panel threaded bushing	5 amperes, 120 v. a-c and 28 v. d-c
JL	1 to 10	2 to 8	1 to 20	nonshorting or shorting	45°	panel threaded bushing	5 amp., 120 volts a-c

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LET'S KEEP

Business Help For Our Colleges Going Full Speed Ahead

"Should our company fold up its program of financial help for higher education now that the Kennedy Administration plans to have the federal government provide this kind of help in a big way?" It is clear why, in the light of campaign promises and plans announced since, this question is being raised in many business firms at this juncture.

What seems far clearer, however, is the right answer to the question. It is a resounding NO! **This is no time for the business community to ease up in what have been its notably successful efforts to help our colleges and universities get out of the deep financial hole in which they are operating. On the contrary, this is the time to put more steam than ever behind the drive of business to increase its financial help for higher education.**

Massive Help Needed

It is easy to understand why any individual businessman or firm might have a rather despairing feeling about the prospect of competing with the federal government, with its almost all-embracing tax arm, in providing financial support for higher education or almost anything else for that matter. But this is not a case of competition. It is a case where our colleges and universities must have massive help all along the line if they are to be put squarely back on their feet financially—a goal of crucial and perhaps decisive national importance. **The business community will continue to have both the opportunity and the obligation to keep on increasing its help for higher education as rapidly as possible.**

To underline this proposition take a look at the chart at the top of the next page. It shows how far the salaries of college and university faculty members continue to lag behind those of other occupational groups in the U.S.A. There has been some relative improvement in the average of faculty salaries in recent years. And the salary improvement in some fields, such as those of science and mathematics, has been very pronounced. But the chart makes clear how badly the average salary of college and university faculty members still lags.

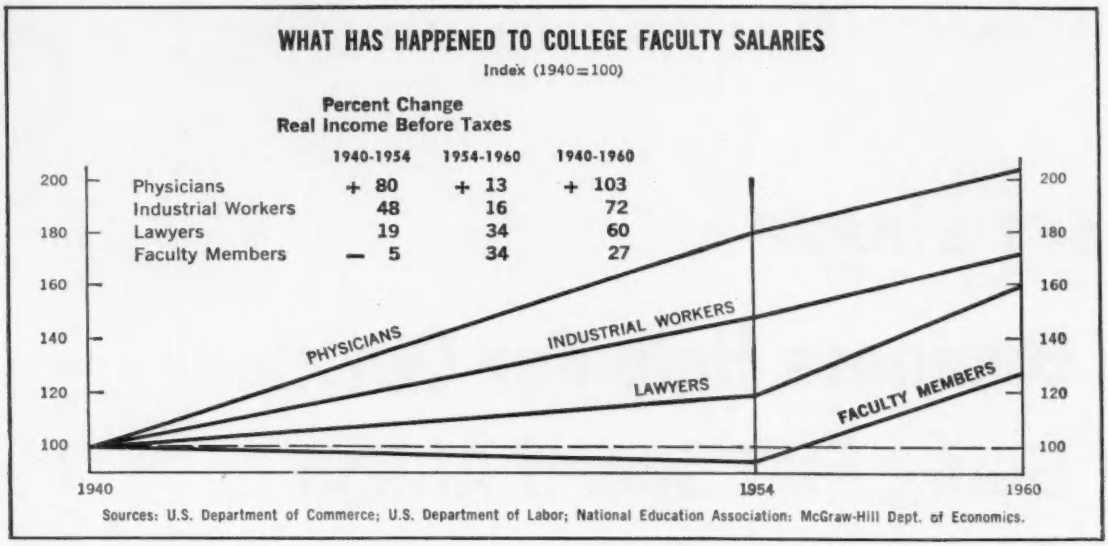
No Federal Funds For Salaries

The plans for increased financial aid for higher education, proposed by President Kennedy, do not contemplate increased expenditure for faculty salaries. This, we believe, is wise whether or not you feel, as many do, that resort to this kind of federal financing would inevitably carry with it federal controls that would ultimately undermine academic independence. The fight over federal appropriations for faculty salaries would be so long and bitter that it would be destructive to the aid program as a whole.

However, what the federal government will not be doing to remedy the deplorable condition of faculty salaries, as reported by the chart, is one indication of the tremendous scope that remains for crucially important help for higher education from business. Manifold other indications are available.

Disaster Escape Route

One of these indications is provided by the careful calculation that the annual income of our colleges and universities must be increased by about $4½ billion (from about $4½ billion to about $9 billion) over the next eight years if the tremendous wave of students



now gathering to descend on these institutions is not to wind up in both a financial and an educational disaster. This wave promises to add more than 2.5 million, or 75%, to college enrollments by 1970.

Thus far, the program for financial help for higher education by business, spearheaded by the Council for Financial Aid to Education, has been a remarkable success in all dimensions. The dollars contributed have increased rapidly—from about $100 million five years ago to about $150 million this year. Contributions of $500 million a year by 1970 are a clear possibility.

One of the inspiring developments increasing this possibility stems out of Cleveland, Ohio. There through their chief executives, an imposing group of business firms have established one per cent of their profits before taxes as their minimum goal for contributions to higher education, to be reached within three years. General acceptance of this goal by business would go most of the way toward getting our colleges and universities firmly on their feet financially.

Mutual Respect Increased

The mutual esteem of the academic community and the business community, an element of enormous importance to a free society, has been increased by the manner in which the program of financial aid has been carried out. In making its contribution, there has been no attempt whatsoever on the part of business to encroach upon the academic freedom of the institutions financially benefited. And the program of financial aid has greatly increased the knowledge, understanding and respect which the colleges and universities and business have for each other.

The Kennedy Administration's program to enlarge federal financial support of higher education is certain to arouse strenuous controversy. As proposed by its Task Force, it avoids some of the most controverial areas of principle. However, the very magnitude of the proposed extension of the federal government's already vast program of financing higher education involves fighting issues.

But if the enlargement of federal aid were to be deeply discouraging to the continued expansion of private aid for higher education, it would be a national misfortune of major proportions. There is no good reason why it should be. On the contrary, there is compelling reason for the business community to continue giving higher education all the financial help it possibly can, thus speeding onward a program that has been and continues to be a major constructive force for our colleges and universities, for business and for the nation.

This message was prepared by my staff associates as part of our company-wide effort to report on major new developments in American business and industry. Permission is freely extended to newspapers, groups or individuals to quote or reprint all or part of the text.

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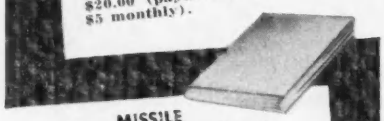

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Aeronutronic Division, Ford Motor Company 60
Aerospace Corporation 181
Aladdin Electronics, A Division of Aladdin Industries, Inc. 154
Allen-Bradley Company 33, 34
Allis-Chalmers 28
American Bosch Arma Corporation . . 53
American Machine & Foundry Company 26
American Optical Company 188
Ampex Instrumentation Products Co. ..... Fourth Cover
Anelex Corporation 160
Assembly Products Inc. 182
Automatic Electric 98
Automatic Switch Co. 115

B/W Controller Corporation 10
Bailey Meter Company 48
Baldwin-Lima-Hamilton, Electronics Instrumentation Division 44
Barber-Colman Company
Wheelco Industrial Instruments Div. 8, 9
Electrical Components Div. ... 213
Barton Instrument Corporation ... 161
Bendix Corporation, The
Eclipse-Pioneer Division ... 158, 159
Utica Division 45
Bourns, Inc. 47
Brush Instruments, Div. of Clevite Corp. 55
Budd Company, The, Budd Instrument Division 204
Burleigh Brooks, Inc. 214
Burroughs Corporation, Electronic Tube Division 69

Calibration Standards Corporation . . 209
Century Electronics & Instruments, Inc. 30
Chance Vought Electronics 183
Clare & Co., C. P. 172
Clary Corporation 72
Clifton Precision Products Co., Inc. Third Cover
Computer-Measurements Company . . 5
Computer Systems, Inc. 73
Conoflow Corporation 177
Consolidated Controls Corporation . . 35
Consolidated Electrodynamics . . . 40, 41
Cubic Corporation, Industrial Division 120
Curtiss-Wright Corporation, Princeton Division 208
Curtiss-Wright Corporation, Inter Mountain Branch 202
Cutler-Hammer Inc. 22, 23

Daven Co., The 206
Daystrom, Incorporated, Potentiometer Division 82
Daystrom-Wiancko Engineering Company 222
Delavan Manufacturing Company . . 163
Delco Radio Division of General Motors 164, 165
DeVar Systems Inc., A Division of General Kinetics Corp. 156
Donner Scientific Company 51
Dressen-Barnes Electronics Corporation 208

Edison Industries, Thomas A., Instrument Division 153
Electric Regulator Corporation 214
Electro-Mech Corporation 42
Electro Switch Corp. 213
Electronic Associates, Inc. 76
Electronic Engineering Company of California 154
Electronics & Instrumentation Division, Baldwin-Lima-Hamilton Corp. 44
Electronics Measurements Co., Inc. . 43
Epsco Components, A Division of Epsco, Incorporated 206
Epsco-West, A Division of Epsco Inc. 2
Essex Wire Corporation, RBM Controls Div. 144

Fairchild Semiconductor Corporation 7
Fenwal Incorporated 64
Fisher Governor Company 148
Foxboro Company, The 24, 97
Friden, Inc. 207

G-M Servo Motors, Components Division of G-M Laboratories Inc. ... 204
Garrett Corporation, The 212
General Ceramics, Division of Indiana General Corporation 50
General Dynamics/Electronics, Information Technology Division 46
General Electric Company
Computer Department 12, 13
General Instrument Corporation, Semiconductor Division 58, 59
Graphic Controls Corporation . . 178, 179
Gurley, W. & L. E. 176

Hays Corporation, The 185
Hewlett-Packard Company 49
Hoskins Manufacturing Company . . 162
Hydro-Aire, Division of Crane Co. . . 184

IMC Magnetics Corporation 36
Industrial Electronic Engineers, Inc. 210
Information Systems, Inc. 66
Inland Motor Corporation of Virginia 61

Kearfott Division, General Precision, Inc. 199, 201, 203
Kidde Aero-Space Division, Walter Kidde & Company, Inc. 180
Kintel, Division of Cohu Electronics Inc. 1

Laboratory for Electronics, Inc. 52
Lambda Electronics Corp. 70, 71
Librascope, Division of General Precision, Inc. ..... Second Cover
Lincoln Laboratory 205
Line Electric Co., division of Industrial Timer Corporation 14
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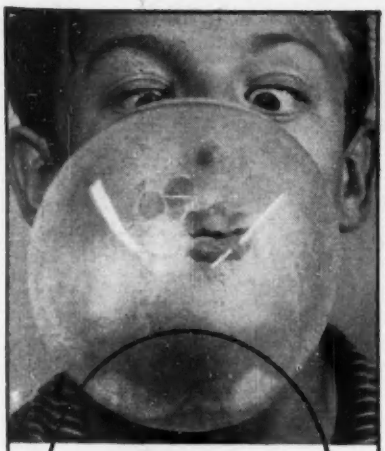

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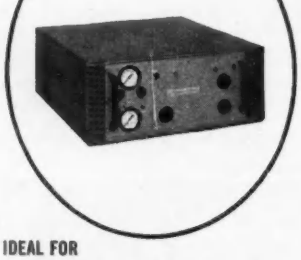

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MB Electronics, Division of Textron Electronics, Inc. 152
Mack Electric Devices, Inc. 206
McDonnell Electronic Equipment . . 54
McGraw-Hill Book Company, Inc. . . 220
Metal Bellows Corporation 209
Micro Switch, A Division of Minneapolis-Honeywell 132, 133
Minneapolis-Honeywell 107, 212
Industrial Systems Division . . . 11, 170 171
Moore Products Co. 15
Muirhead & Co., Lt'd. 211

National Acme Company, The 75
Norden Division, United Aircraft, Ketay Department 78
Norden Division, United Aircraft Corporation 38

Pace Controls Corp. 205
Pall Corporation 192
Philco Corp., Lansdale Division 80
Philips Electronics Inc., Instrument Division 191
Potter & Brumfield 167
Potter Instrument Company, Inc. . . . 16

RBM Controls Division, Essex Wire Corporation 144
Radio Corporation of America Semiconductor Distributor Div. . . . 31
Reeves Soundcraft Corp. 20
Republic Flow Meters Co. 189
Rheem Manufacturing Company, Electronics Division 191
Rosemount Engineering Company . . 210

Sanborn Company, Industrial Division 17
Sangamo Electric Company 67
Seneca Falls Machine Co., Electronics Div. 193
Servomechanisms, Inc., Mechatrol Division 166
Sigma Instrument, Inc. 194
Sola Electric Co. 146
Space Technology Laboratories, Inc. 68
Struthers-Dunn, Inc 174
Superior Tube Company 175
Swartwout Division, Crane Co. 173

Tally Register Corporation 62
Taurus Corporation 206
Taylor Instrument Companies . . 18, 19 140
Teletype Corporation 37
Thermo Electric Co., Inc. 108
Transitron Electronic Corporation . . 150
Trinity Equipment Corporation 6
Tung-Sol Electric Inc. 63

United Electric Controls Company . . 190

Veeder-Root Incorporated 142
Vickers Incorporated, Division of Sperry Rand Corporation 155
Victor Electronics Division, Victor Adding Machine Co. 169
Vidar Corporation 57

Wallace & Tiernan Incorporated . . . 186 187
Walter Kidde & Co. Inc., Kidde Aero-Space Division 180
Weston Hydraulics Limited, A Subsidiary of Borg-Warner Corporation 136

PROFESSIONAL SERVICES 220

CLASSIFIED ADVERTISING
F. J. Eberle, Business Manager

EMPLOYMENT OPPORTUNITIES 218-220

EQUIPMENT
(Used or Surplus New)
For Sale 220

ADVERTISERS INDEX

Bechtel Corp. 220
Esquire Personnel 220
IBM Development Lab., International Business Machines Corp. 218
Los Alamos Scientific Laboratory, The University of California 220
MIT, Instrumentation Lab. 218
Rankin Co. 220
Ridgefield Instrument Group, Div. of Schlumberger 220
Sikorsky Aircraft, Div. of United Aircraft Corp. 219

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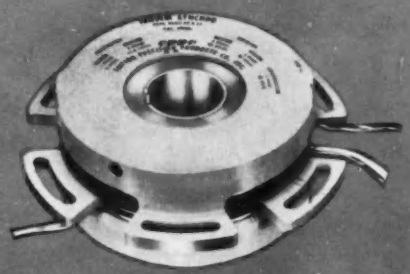

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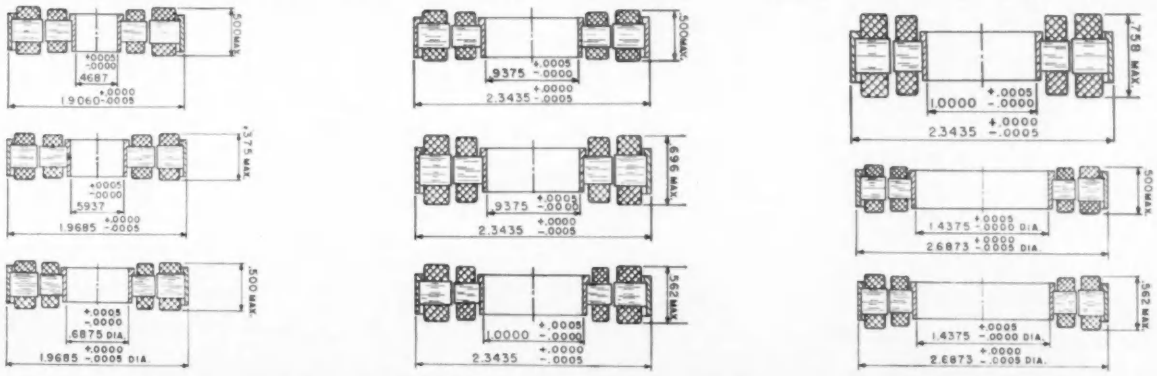

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Alexander M. Poniatoff, Founder and Chairman of the Board of Ampex Corporation, discusses magnetic tape recorders.

How to get accurate data on a small recorder

Ampex's new CP-100 nicely balances four desirable qualities

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Portable. We'll frankly admit it takes two men to carry it – not just one and a half. But by calling in an occasional fractional man (or by using an accessory dolly) you gain exactly the needed performance that portables have lacked until now. In laboratory use, the CP-100 is "bench-top equipment."

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Universal. Yes, in numerous ways. The CP-100 isn't fussy about power; takes 115 or 230-volt AC at 50, 60 or 400 cycles or 28-volt DC from batteries or generator. Kinds of data: direct or FM-carrier, by interchangeable plug-in amplifiers. And it records and plays back as well.

The essential data

Model: CP-100 Compact Recorder/Reproducer. *Reel size and tape width:* 10½-inch reels with ½- or 1-inch tape (as specified). *Types of recording:* direct or FM carrier by plug-in interchangeable amplifiers. *Tape speeds:* 60, 30, 15, 7½, 3¾ and 1⅞ ips. *Frequency response:* direct, 300 to 200,000 cps ± 3 db at 60 ips; FM carrier, 0 to 20,000 cps at 60 ips; response at other speeds proportionate. *Tape compatibility:* yes, with Ampex FR-600, AR-200 or interchangeable with FR-100, FR-1100, 300 and 800 series.

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